Navigating the Air

First ascent of Aero Club at West Point

Navigating the Air

A scientific statement of the progress
of aëronautical science up to
the present time

By

The Aero Club of America

Illustrated with photographs
and diagrams

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EDITORIAL NOTE

The inventions described in the succeeding pages are the result of years of experiment and patient effort; sometimes amid the discouragement of apparent lack of success. They contribute a panoramic history of aëronautics in this country and in Europe.

To reach the goal of human aërial locomotion requires the thoughts and works of many men; therefore, it is most profitable that there should be gathered together the reports of aëronautical experiments.

Though no responsibility is assumed by the Aero Club of America for the statements of the individual writers, these papers were collected pursuant to a resolution passed by the Board of Directors of the Club.

Israel Ludlow,
William J. Hammer,
Augustus Post,
Publication Committee.

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The National Geographic Magazine, published by the National Geographic Society, Washington, D. C.: "A few Notes of Progress in the Construction of an Aërodrome," by Dr. Alexander Graham Bell.

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PREFACE

THE AERO CLUB OF AMERICA

BY CORTLANDT FIELD BISHOP

FOUNDED in the summer of 1905 by virtually the same men who had organized the Automobile Club of America, the history of the Aero Club of America is necessarily a very brief one. The objects for which it was formed are set forth in detail in its constitution, but they may be summarized in the brief statement that the club exists for the promotion and development of the science of aërial navigation. Founded by men who had almost without exception never made an ascension in a free balloon, the club has in one year of existence earned for itself a position in the world of sport, and it is to be hoped it has opened up a brilliant career for itself in the future.

Although the Aero Club is the first organization of aëronauts to be formed on the American continent, it has had a number of precursors in Europe, where the science of aërial navigation has for many years received careful study. It is not my purpose to enter into a history of balloons in this connection. Suffice it to say that the revival of this sport which took place in

Europe in the later years of the nineteenth century did not reach this country till 1906. Many of our countrymen who had seen balloons daily passing over Paris, or who had witnessed the aërial contest at Vincennes in 1900, did not realize that a balloon voyage was not an uncommon thing in the United States a generation ago. Parachute jumping, a perilous adventure, and one requiring skill and courage, had become a popular catchpenny attraction at country fairs, but the sport of ballooning as practised by our forefathers had become quite lost sight of.

So when the Aero Club of America organized its first exposition last January, balloons were imported from Paris and the public was given the opportunity of seeing what they were like. Photographs of balloon ascensions were displayed and an effort was made to arouse a popular interest in the sport as it is practised abroad.

This show was followed by a number of actual ascents from different places in the Eastern States and thus people in one section of this country at least were given an opportunity to become familiar with aërial navigation in its simplest and safest form.

The home of the Aero Club, the city of New York, is unfavorably situated as a ballooning center. The ocean, the one peril of aëronauts, is close at hand, and only with a wind from a southerly direction is an ascent to be made with perfect safety. The gas question is also an important factor and the Aero Club has found at Pittsfield, Mass., a station combining the features necessary for successful ascents—distance from

the sea and an abundant supply of coal-gas. The great drawback is its distance from New York and other centers of population.

The Aero Club has acquired two balloons, one of them, the *Centaur,* having made the record balloon journey from Paris to Russia in 1900. These aërostats are available for ascensions by members, and it is hoped that before long the club will be able to acquire newer balloons. Both the French and British clubs have special balloons of their own, and during the season ascents are made at reduced rates for the benefit of the members who can not afford their own aërostats. So great is the number of those who desire to participate in these excursions that lots are drawn by applicants for the privilege.

Such is not the case in the United States, where it takes a good deal of persuasion before the average person will go up in a balloon. Americans are not supposed to be lacking in courage, but they look forward to a balloon ascent with fear and trembling. There really should be nothing to inspire fear in an ascent with a competent pilot. Accidents have been rare, and the records of European ascensions in these last years are almost free from them. It is a noteworthy fact that women show much less fear than do men.

Another drawback to ballooning in this country is the difficulty of communication in the inland districts and the absence of good roads, which prevents pursuit by automobiles. This makes the return to the starting-point more difficult and less pleasant for ladies, and often involves the spending of the night in discomfort

after descent. Yet, in spite of all these objections, the writer believes that ballooning will yet become popular in this country. Americans are conservative and slow to take hold of anything novel. They were reluctant to take up the automobile; its introduction met with fierce and violent opposition, yet in this year of grace there is no country where automobiles are in more common or universal use than in America.

So it will be with balloons, and the time will come when aëro clubs will be founded in the chief cities of the United States. Already Philadelphia and St. Louis have followed the lead of New York. Within the not distant future the Aero Club of America hopes to form a national federation which will unite the aëro clubs of this continent and will act on the lines of the French national organization.

The first needs of the Aero Club of America are suitable quarters and a park equipped with a proper balloon garage. As has already been mentioned, the city of Pittsfield, from which a number of successful ascensions were made last year, combines all the requisites as a site for an aëro park—proper geographical situation and abundant facilities for making coal-gas of proper specific gravity, and for promptly inflating balloons.

What the Aero Club needs is a wealthy patron to do for ballooning what Mæcenas did for art and literature in the time of Augustus. It needs a house and a balloon shed, and it must appeal to its friends for funds. Although the club has now nearly 250 members,

nearly as many as the Aero Club of the United Kingdom, its revenues are small, and all of these must go for current expenses.

There is also needed a permanent staff of expert workmen to attend to the inflation of balloons and to their care and repair, both before and after each ascension. That this will all come in due time we do not doubt. The French Aero Club procured these things and more, in a very short time, through the liberality of a few of its members.

The first step, therefore, in the propaganda undertaken by the Aero Club of America is the popularization of ballooning as a sport, especially among the leisure and more wealthy class. It is not to be my task in this article to decant upon the delights of ballooning as a pastime. Many others have done this and in an eloquent fashion. Suffice it to say that the balloon, with all its limitations, is to-day the only form of aërial navigation that, ordinary care being used, is free from danger.

It will be argued, and it may be admitted, that the balloon of to-day is virtually what it was when first invented a century and a quarter ago and that there has been no progress in its development. Yet the fact remains that no form of sport gives greater delight to its devotees or produces more agreeable and novel sensations. To sail over the country, viewing it from a height and in a variety of lights, without noise, smell or vibration, is indeed a pleasant experience. That the balloon becomes the plaything of whatever wind blows

is of comparatively small importance, when we consider that the object to be attained by the ascensions is pleasure or recreation.

In order to throw safeguards about this sport it will be necessary to adopt rules regarding the issuing of licenses to those who have proved themselves capable of handling balloons. The Aero Club proposes to follow in this respect the example set by the French Aero Club, which requires a strict course of training before it grants a license to an aërial pilot. A few years ago the French club counted only two or three pilots among its members. Now a large proportion of them hold these coveted certificates, and several members have two hundred ascensions or more to their credit. One member has several times made two ascents in a day, and another recently made his honeymoon journey in a balloon. As yet only a half dozen Americans hold pilot licenses from the French club, one member in particular having made his ten required ascents within the space of one month last summer.

In addition to the reasons already given, the Aero Club believes in promoting ballooning as the most practicable means of studying the air and stimulating public interest in aërial navigation, the dream of the future.

The Aero Club of America was fortunate in being organized in time to become one of the original members of the Federation Aeronautique Internationale, which was founded in 1905, and is composed of the eight leading aëronautic clubs, from as many countries.

This organization is in reality an international federation of aëronauts, as its name implies. It holds an annual conference in some one of the world's capitals, and the number of delegates from each club is proportioned to the number of cubic meters of gas consumed in its ascensions during the previous year.

It was to this body that Mr. James Gordon Bennett presented for competition his International Challenge Cup, and it was under its auspices that the first contest was held for this cup, on September 30, 1906. The honor of winning this cup fell to the Aero Club of America, represented by one of its honorary members, Lieutenant Frank P. Lahm.

As a result of this victory, it devolves upon the Aëro Club of America to organize and hold the contest for this cup in 1907. Such an event will be of world-wide interest, and cannot fail to arouse a healthy interest in ballooning as a sport throughout the United States. The club has selected St. Louis, a centrally located city, in order that record flights may be made whatever the direction of the wind. Eight nations—France, Germany, Great Britain, Belgium, Switzerland, Italy, Spain and the United States—each with three balloons, are entitled to compete, and the contest will be in all respects international. It is estimated that the great European balloon contests of 1906 were each witnessed by two hundred thousand spectators, and it is hoped that this race of 1907 will command at least equal interest. It will require all the resources of the Aëro Club of America, and all the energies of its members, to prop-

erly organize and conduct this contest. This will, of necessity, be its chief task for 1907, and to this all else must be subordinated.

While a large entry list from the foreign clubs is desired in order to enhance interest in the contest of 1907, the Aëro Club of America does not purpose to let the cup be carried off without a valiant struggle to keep it over here. We hope that the history of the *America's* Cup will be repeated and that the International Cup has crossed the ocean never to return. The club has been assured that three balloons of 2200 meters, the maximum capacity permitted under the rules, will be available for its champions. There are already many applicants for the honor of being chosen as one of the three defenders of the cup, and it is certain that there will be a large field from which to make the selection.

The greatest interest has been displayed throughout the civilized world, and special facilities will be offered to all aëronauts visiting St. Louis for this contest. Through the liberality of various citizens and organizations of that city the Aëro Club of America has been enabled to offer cash prizes amounting to $2500, to be distributed among the contestants winning respectively second, third, fourth and fifth places. This is in addition to the sum of $2500 to be given by Mr. Bennett to the winner of the cup. The Aëro Club of America also offers a prize to the contestant remaining longest in the air.

As a further stimulus to ballooning, the Aero Club has founded and offered for competition a challenge trophy to be known as the Lahm Cup and to be held in

turn by each member of a recognized Aero Club of this country or abroad who exceeds the distance—402 miles—covered by Lieutenant Lahm in winning the International Cup, the record of the previous holder of the cup.

The Aëro Club will endeavor to introduce and popularize in this country the various contests in connection with ballooning which have proved so attractive in France. These include the pursuit and capture by several balloons of a pilot balloon having a certain start; also a contest by several balloons, the winner to be the one who lands nearest to a given spot designated on a map beforehand. Prizes will also be given to automobiles which shall start in pursuit of balloons and reach them within a given interval after their launching.

Up to this point we have considered aërial navigation only, so to speak, in relation to its past and to the desire of the Aëro Club to revive what has been forgotten, to do what other nations have been doing, and to bring aëronautics in the United States up to date and place them on the same level as it stands in European countries. But in recent years, and more particularly in the last few months, the science of aërial navigation all over the world has taken a sudden leap forward. Man has determined to fly, and the goal he has sought for centuries has all but been reached. America is far ahead of all Europe in actual progress in dynamic flight: *vide,* Langley, Chanute, Wright Brothers, etc.

It should be the province of the Aëro Club of America to encourage all attempts at a solution of the flying problem, and it should investigate and report upon

every invention or contrivance which seems to have a reasonable chance of success. A technical committee composed of experts and scientists, in whose names and reputations the public will have confidence, will be appointed. This committee will be authorized to solicit and receive subscriptions, to be spent judiciously and when there is a good chance for a profitable return. Only by lavish expenditure and by continued experiments can success in flying be achieved. In France all that has been accomplished in this direction has been largely due to the generosity of a few patrons of aëronautics. The most successful steerable balloons now owned by the French government are due to the Lebaudys, who spent large sums of money in experiments, and whose wealth made possible their construction. The rich prizes offered by M. Deutsch de la Meurthe stimulated Santos-Dumont to achieve his notable flight around the Eiffel Tower. M. Deutsch has built at his own expense a large air-ship which recently manœuvered near Paris, and he has offered prizes of great value for aëroplanes.

Is there not in all this land of swollen fortunes some one who will offer a prize of sufficient size to reward the inventor and repay him for all the years he has to spend in unsuccessful effort? To England belongs the credit of having invented the steam railroad engine; to France belongs the honor of producing the automobile. Shall the United States of America allow themselves to be left behind in the race to bring forth a flying machine that will fly, and thus confer one of the greatest of benefits on mankind?

It is not the purpose of this article to discuss the relative merits of the aëroplane and the aërostat, or to descant on the "heavier than air" or the "lighter than air" aspect of the problem—it is to call for some action that will result in the construction of practical flying machines. As already stated, a great deal of persistence and endless experiment are necessary. But, above all, there is the question of expense to be surmounted. In England and in France at this day more than a hundred thousand dollars in prizes awaits the successful inventor. In this country, as far as the writer can ascertain, not one cent has been offered in prizes for aërial navigation. The Wright Brothers, of Dayton, Ohio, who are commonly believed to have discovered the secret of aërial navigation, have had to discontinue their experiments and seek financial aid from foreign powers in order to construct aërial engines which may be used in wars to our destruction.

It is the opinion of many who have devoted attention to the question, that human flight, to be successful, must be brought about by the aid of appliances of comparative simplicity both in their construction and in their operation. Many inventors have carefully studied the flight of birds, hoping that from this source, by some sort of analogy, the secret could be discovered. It is generally thought that successful human flight must be dependent to a great extent upon aptitude and special training quite as much as upon a complicated and delicate apparatus. It is probable that when the final solution is reached, we shall be astonished at its simplicity.

Toward this solution the efforts and experiments of

inventors throughout the civilized world are to-day converging. It is not impossible that the problem of human flight may be solved simultaneously by persons working at different places, and each ignorant of the other's experiments. Such things have happened before, and history may repeat itself.

The Aëro Club of America, confident of the ultimate success of its members, will do all it can to speedily bring about a satisfactory public demonstration of human flight. It believes that the end sought has been attained by at least two of its members, and it pledges to them its support and influence. Immortal fame awaits the man who shall make aërial flight a reality to the human race; and he who by financial assistance helps to achieve this result will receive a goodly share of this renown.

Is there not in all this land of swollen fortunes some one who will offer a prize of sufficient size to reward the inventor and repay him for all the years he has to spend in unsuccessful effort? To England belongs the credit of having invented the steam railroad engine; to France belongs the honor of producing the automobile. Shall the United States of America allow themselves to be left behind in the race to bring forth a flying-machine that will fly, and thus confer one of the greatest of benefits on mankind?

Let a Mæcenas arise among us. Let him offer a suitable sum of money to go to the man who produces an aëroplane that fulfils certain conditions. Let the tests be held under the supervision of the Aero Club of America, or of some similar organization. Then we

shall see whether the genius of American inventors cannot solve this fascinating problem on which so much depends. Competition is keen; even now there are many who have all but attained the goal so much desired. There is not a moment to be lost if American wealth and American genius are to carry off the palm.

INTRODUCTION

PRACTICAL AIR CRAFT

By Carl Dienstbach

IN the strictest sense of the word only two specimens of self-moving air vehicles can be called "practical," namely, the two motor balloons of the Lebaudy type which have been bought by the French government and entered upon a term of regular military service. But in view of the complete failure which has been for so long strictly the rule with the many attempts at "navigating" the air, we may extend the term "practical" to all aëronautical machines, which have been in any respect truly successful. A review of such craft, from the first to the last, and a critical appreciation of the principal points of merit in each case may prove interesting.

The oldest instance would appear to be the motor-driven balloon, *La France,* which in 1884 was the first air-ship that had ever returned to its starting-point. It was constructed at the expense of the French government by two officers, Captains Renard and Krebs, the former being the original designer. The results of their labors, in purely aëronautical engineering, have

hardly been surpassed even by the very latest constructions. They obtained a speed of between fourteen and fifteen miles an hour for a balloon of 179 feet length and 27½ feet greatest diameter with only 8½ horsepower. This splendid performance they owed to a propeller of nearly 24 feet in diameter, running at only 46 revolutions a minute; to a fishlike shape of minimum resistance in the gas-bag, a lucky anticipation, vindicated twenty years later by Prof. A. F. Zahm's investigations; to the first application of the elaborate, long (128 feet) stiffening frame, since become so common, which they wisely covered with cloth and fashioned into a spacious car; to a very rigid and efficient rudder mounted at the right place; to the perfecting of the apparatus for maintaining internal pressure by means of a ballonette; to the absence of a net and its friction, a substitute being cleverly employed; and last, but not least, to correct proportioning and superior material and workmanship. The weight of their motive power, electricity, was moreover, tremendous, close to 170 lbs. to the horse-power (see "Moedebeck's Handbook"). Still the weight of the (primary) battery alone seems to have been kept within more reasonable limits: 40 lbs. to the horse-power (Tissandier, "Histoire des Balloons"). It seems curious that many of *La France's* numerous successors failed in just one of the points where she excelled, for instance, the totally misplaced rudder of De Bradsky.

The next successful step in the history of aërial automobilism takes us to a very different field. But here it seems *les extrèmes se touchent.*

Maxim's aëroplane was the first actually to rise from the ground, as *La France* was the first balloon to return to its starting-point. The enormous size of the aëroplane is, moreover, in one respect explained by the designer's habit of contrasting the possibilities of the navigable balloon with those of the aëroplane in his writings, where the latter always appears to be of equal dimensions. There were, however, circumstances rendering gigantic proportions imperative. The very mechanism of modern locomotion may be said to have been created by Mr. Maxim. His motor contained virtually all that made the modern steam automobile possible. The large scale was a great help in evolving that ingenious piece of machinery from the comparatively cumbersome steam engine of 1890. He, moreover, founded his first design on a somewhat incomplete knowledge of aëroplane effect. The influence of shape, the all-important question of head resistance, were as yet but imperfectly understood. Consequently, no very high lifting capacity per unit of apparatus could be obtained, and to transport human beings the machine had to be of great size and weight, which made it in turn necessary to carry three men for handling it. The question of stability was just barely approached, all practical data on this most important subject being missing. Still there were two kinds of steadying devices, which have since been successfully applied to other apparatus, namely, the "dihedral" angle of the Langley models, and the horizontal rudder of the Wright gliders. It seems quite possible that with proper devices for operating the latter by power,

with the required suddenness and speed, and, specially, with a sufficiently trained helmsman, the machine might have been successfully navigated. It seems only to have been out of the question to use it experimentally to the end, making it the instrument with which to acquire the needed knowledge. The slightest mistake might have been fatal to that size and method of construction. Therefore, although the first actually power-supported machine, it cannot be said to have demonstrated the solution of the old problem.

Lilienthal's gliding machine, however, stepped into the breach at just the right moment. Appearing simultaneously with its giant rival as the first actual "flyer," it became the great original discoverer of the first elements of those laws which govern real free flight, but it started a tedious investigation, and opened an endless vista of difficulties. It is left to a later day to bring adequate appreciation of what Lilienthal has actually done. If he succeeded in breaking the ice and showing a way past previous stumbling-blocks, the fact is due to his novel attitude toward the problem, and his ability to view the flight of birds in the true engineering spirit. In this he was aided by an absorbing love of nature, as well as by philosophical and poetical gifts, a rare and happy combination, favored by the trend of the German temperament. It brought him to the threshold of all those treasures of aërodynamical and aërodromical science—the appreciation of the difference in the flying efficiency of variously shaped surfaces, of the nature of the wind, and how it may be dealt with, which eleven years after his death became the founda-

tion of the first true man-flight. Of all contemporary research only Maxim's work on the aërial screw propeller stands comparison with Lilienthal's, and it, in fact, happens to form such an opportune supplement (Lilienthal neglected the screw) that in the midst of a vast chaos of contradictions and errors the discerning student might have found a good deal of comparatively reliable and comprehensive information as early as 1896. It is precisely that part of Lilienthal's work, which he did not try to reduce to "exact science," *viz.*, striking observations and ingenious single deductions, which seems to have most value, and in the light of modern experience these may be brought to better account that he realized himself. His grasp on the subject seems to have been rather that of a Plato than of an Aristotle. He went to the depths without embracing the entirety, and that circumstance may account for his tables on air-pressure still remaining more or less incorrect, and for his scant success in improving his original gliding machine. The naturalist seems in the end to have got the better of the engineer. For some time before his death he fairly reveled in getting on the closest of terms with a whole colony of storks on the roofs of the Prussian village of Rinow, and he unraveled many of their flying tricks. But by that time he must have been losing the eyesight of the engineer with which to recognize the difference between the sort of simplicity in his own wings and those of the stork. Dropping a somewhat unpromising attempt to copy the flapping flight by a theoretically most perfectly designed machine, he de-

voted his time to endeavors at discovering what sort of manœuvers, with his primitive gliding surfaces, simply arched kites, would derive from the wind that coveted continuous soaring support, and he was killed by getting upset. Birds may become sirens to the aërodromical engineer who had better shut his eyes at times to the truly stupefying feats they perform with seemingly ridiculously simple apparatus and most inadequate motive power. In summing up the life-work of this great pioneer and martyr we may say, that, like Moses, he led others to the promised land but could not enter it himself. He fetched the material and outlined the plans for the building, but seemed to lack the mason's skill for putting them together. After his work the gliding machine became a "continuous performance," and was in due time turned into the practical flying machine.

O. Chanute, A. M. Herring, and a little later, Wilbur Wright, started just where Lilienthal left off, in the same spirit and direction, but with evidently superior judgment as to the engineering aspect of the matter. Leaving this direct line of steady progress for the review of other results, we find some of them are doubly interesting because they prove that for the undaunted there is more than one way to a goal.

The wonderful work of Professor Langley, the great originator of the science of aërodynamics, and that of his able assistant Charles M. Manly, might be characterized as the starting point of exact aërodromical science. Langley was practical, for he realized from the outset the formidable character of the

stability problem. Unlike Lilienthal he learned from artificial birds. Small models which could keep their balance in flight had been produced by persistent trying. The very ingenious design of Penaud was studied, copied and modified. To make things doubly certain two sets of carrying surfaces were arranged one behind the other. The conclusion seemed obvious, that an apparatus is more stable with two separate centers of pressure; but the rear surfaces thus lose greatly in supporting efficiency, while still offering the same amount of drag. The reason of this phenomenon is found in the fact that they have to rely for support on an air current to which the front surfaces have already imparted a downward direction, making it literally uphill work for the rear ones, but in turn tending to keep them in the same place, and this again increases the stability. Regulating devices were further added, and a design was produced of small lifting efficiency, but with a fair amount of automatic "artificial" stability. All there remained to do seemed to be to increase the size by degrees until finally an operator could be carried; in reality a truly formidable task. The first machines, which for their size had to be of extreme lightness, were most difficult to build and just as hard to handle. It required angelic patience and perseverance to set right one microscopic detail after the other, until, after years of the most painstaking and expensive labors, there was at last a flight accomplished which did indeed eclipse any preceding one. A. M. Herring had lent a helping hand about that date, but after the advent of Engineer C.

M. Manly the whole field was gone over again and broadened. The most valuable data was brought to light in nearly every line of aëronautical engineering, and a new science was actually created contemporaneous with that independently developed by the Lilienthal school. When the epoch-making light and powerful explosion motors of Manly's design were substituted for the steam engines hitherto employed, there was a saving in weight which allowed a far more solid construction of the framework.

A most successful new model, three times as strong and more than twice as heavy, though not much larger than the former ones, was the next fortunate result, and finally this was duplicated on the man-carrying scale—a fourfold increase in size answering the purpose. But here Langley's practical point of view became well nigh pedantic. No departure would he permit from the design and method of operation of the smaller machines which had flown, formidable practical difficulties notwithstanding. The ensuing accidents in their launching (all the Langley machines were designed to be thrown or shot into the air to start their flight), the public misrepresentations and the most regrettable effect on this highly creditable enterprise are still fresh in the memory. Let us hope that the future will soon show us a renewal of the experiments with this machine under Mr. Manly's direction. The "following surfaces" system, provided there is power enough, may have some advantages as to safety, and the automatic plan of controlling the equilibrium of the generously sized models, of which

the man-carrying machine is an exact counterpart, would insure easy control.

We have next to record the beginning of the new era of the popularization of aërial automobilism. This was reserved for the aërostatic air-ship, and the name of Santos-Dumont will forever be emblematic of an entirely new departure in aëronautical endeavor. It was a kind fate which put enthusiasm and mechanical ability into the mind of a Brazilian millionaire, living in that intellectual center, Paris, and made him also a star member of the most famous constituent of the present "Federation Aeronautique Internationale," the "Aero Club de France." He had full command of the most up-to-date developments in the construction of light motors, which may be said from that time to have been taken off the mind of the aëronautical experimenter and intrusted to commercial engineers. After several more or less futile attempts he developed a balloon design which did not come up to *La France,* though it copied several important features. Santos-Dumont secured a happy combination with a far superior motor, the speed record was decisively beaten, the first prize ever offered for an air-ship performance won, and, what is the most important, regular aërial return trips were soon established.

A few trial trips, however successful, are soon forgotten, but three years of regular air-ship navigation were sufficient to revolutionize public opinion. That one sort of a fairly controllable air-vehicle was now at the beck and call of anybody who cared to pay for its

construction, was soon recognized, and many sprang into existence at first in Europe, a little later in America, ushered in by the enthusiastic enterprise of Stevens, Baldwin and Knabenshue.

Before dismissing the past century we have, however, to pay closer attention to a few important events in what has been designated the Lilienthal School, and also to another independent move of the Langley order. A. M. Herring, a gifted engineer, turning from very ingenious and successful small scale work to man-carrying machines, after a few trials discarded the Lilienthal type, which he had already slightly improved, and by applying the results of his former experiments produced that far superior automatic gliding machine, which, through the experiments under O. Chanute's approved supervision, was to become famous all over the aëronautical world. Judiciously adding compressed-air power and perfected propellers, and carefully establishing the novel *modus operandi,* he claims he became the first human being ever carried in steady free flight by a power-supported machine. The nature of the motor of course limited the distance. Most unfortunately, a fire in his workshop prevented him from substituting a steam power plant, which in lightness and ease of control was remarkable and of diminutive scale, and obliged him to fall back on models. But he presently produced the first, pigmy-sized, yet smoothly running and fairly powerful, though extremely light, gasolene motor, which he applied to a strong medium-sized, but very light, model of the type of his gliding and flying machine that ante-

dated Langley's third and larger one and flew just as steadily with only one set of carrying surfaces. This was done by virtue of Herring's original automatic equilibrizing devices, which it demonstrated fully, and of course with much less power consumption.

In the meanwhile there had appeared in the field the brothers Orville and Wilbur Wright, young engineers, who took up the work on the gliding machine just where Chanute left off. Following in Lilienthal's footsteps they still built up from the bottom, and along with their exclusively full scale work they did a great deal of laboratory experimenting to establish their own correct aërodynamical tables. Control in their machines, as in Lilienthal's, had to depend on bodily skill, but there were far more chances of progression in that difficult art, because they replaced the cumbersome shifting of weight by surface movements of flash-like rapidity.

Lilienthal's fundamental data were corrected, and in the design of the machine many practical, happy ideas were embodied. The work was very thorough and it was soon rewarded by new records being established in its results.

Europe had meanwhile waked up to aërodromical possibilities. Suddenly the merits of W. Kress, the old Vienna engineer, whose most creditable small scale work antedated everything else, and who had established a remarkable instance of fair automatic stability and low power consumption in aëroplane models, were recognized by leading scientists and officials in the Austrian capital, and he was provided with funds to

duplicate his largest rubber-driven model on a comparatively gigantic scale. As was to be expected such a formidable task exceeded the facilities at command. The remarkable automatic stability of his models, even in high winds, Kress attributed to a multiplicity of centers of pressure and proper arrangement of rudders and surfaces, which followed each other in such a way as to be out of each other's wake.

Claim to a high place in practical air craft records Kress seems, however, to merit by quite a different set of experiments on a fairly large scale, namely, his lifting screw apparatus, now known as "hélicoptère." To supply a more handy and efficient substitute for the military captive balloon, he tested two superposed propellers, turning by means of a hollow shaft in opposite directions around the same axis, of over 12 feet in diameter, and only 9 lbs. weight each, thanks to an ingenious, sail-like construction. He thus obtained at a maximum speed of 120 revolutions per minute, a maximum lift of 82 lbs. per horse-power. The tests were thoroughly reliable, the apparatus was safe and sound, and the results obtained eleven years ago surpass all others in the same line, but they were little known. The equilibrium question was left untouched and unsolved, because the electric motor proved too weak for lifting the whole weight of sixty-nine pounds. Recently, however, such progress has been made in this direction on a small scale by Mr. W. R. Kimball, that the practical hélicoptère seems assured in view of such light-weight construction.

The new century opens with the name of Zeppelin.

The first real ship of the air, of appropriately enormous size, built as a rigid hull of aluminium-framing, and strong cloth covering, with a series of pressureless, well protected gas-bags inside, put in an appearance above Lake Constance. Its inventor at first narrowly escaped the fate of becoming the Maxim of the aërostat. Like the latter's aëroplane, his ship appeared too large to be steered. Its special points were: the extreme length in proportion to the diameter; the placing of multiple propellers on the level of the hull; the multiplicity of gas compartments; almost complete protection of the gas from sun heat by a ventilated air space between the outer shell and the interior gas-bag, and decentralization of the load, by using two sets of motors with short transmissions arranged in two cars close to the hull. This was altogether a design with truly astonishing possibilities, of which, however, almost none were realized in the initial construction. Paradoxically, the propellers were at first too small for the weak and heavy motors. With stronger ones at high speed they proved big enough eventually.

We are now very close to the last startling events, which have practically established true aërial navigation: the crowning of Lilienthal's life-work by the "Wright Flyer," the first fully successful power-supported, high-speed, man-carrying flying machine; the first truly reliable aërostatic air-ship; the "Lebaudy" motor balloon,—the brilliant and surpassing performance of the last Zeppelin model, and, last but not least, the popularization and "booming" of the so little understood power-supported flying machine.

Of "the Wright glider with power applied," that startling outcome of the steady line of progress which leads from Lilienthal on, little is as yet known other than the accounts of the really wonderful, though amply verified performances. The principal merit in this first instance of a really practical motor aëroplane (*viz.,* a machine which can be used and abused more than once) seems to consist in the size adopted, which is neither Maxim's two tons of machinery, nor the light apparatus with the proportionately enormous load of others. The first so-called "Wright flyer" was a happy medium, a machine of generous size and weight, with quite a moderate load to carry, consequently by far the staunchest and strongest ever constructed, and excellently suited to adapt itself to all the knocking about unavoidable at the beginning of practical power flight. There was nothing automatic about the control, and most cautious, frequently repeated trials were required to slowly but surely evolve the means and the science of navigation. Winds of high velocity were not avoided, though from a motor machine their vicissitudes appeared more ugly than ever; but there was no weight to shift and no check to the operator's skill, and in the end, with some changes in the controlling mechanism, the mastery became well nigh complete. Heights of flight up to 60 feet were occasionally reached; steering in all directions with or against the wind was successfully performed. The inventors, however, are of the opinion that any demonstration of their machine before technical people, would invalidate, if it did not reveal, their secrets, and before they will

make binding contracts, or sales in advance of the demonstration, or else become convinced of the futility of such attempts, the world will not be treated to a share in their triumph, and a few hundred people in Dayton, Ohio, are so far the only enviable, and trusty witnesses.

One curious point the brothers seem to have established: that a really successful air-craft will develop speed in excess of anticipations based on the motor's efficiency. This is further borne out by the final complete success of the gas-supported air-ship which has been attained simultaneously. Two wealthy Frenchmen, the brothers Pierre and Paul Lebaudy, provided a very capable engineer, H. Julliot, with the means to carry out to his heart's content all his patiently matured plans as to how to build *the* perfect airship. As a result, there was at last a really substantial advance over *La France* in motor-propelled gas-bags. The mechanism worked to perfection; steering both horizontally and vertically was done most efficiently; and the elaborate devices for keeping the ship on an even keel, which constituted the principal novelty of the design, proved a shining success as it insured unprecedented speed. Without making a radical change of system, it seems hard to imagine further essential improvements, except perhaps in strengthening the motor, or in changing details, as Von Parsefal did in Germany. Using the design of the elongated military captive "kite" balloon as a basis, he succeeded in constructing, for the special requirements of army service, a speedy large craft without rigid part of any bulk.

An entirely different method was attempted by Von Zeppelin. His most complete recent success, which in magnitude outdistances everything else, is yet to be recorded. But for the "Wright flyer" he would now hold the speed record in navigating the air—fully 34 miles an hour, amply verified by the most careful scientific measurements; only one mile slower than Maxim's aëroplane running on the track, or equal to the average railroad train. The credit is due to the large scale of his construction.

By the law of air accumulation in front of a moving body, the head resistance becomes proportionately less for one big body than for many small ones, though the cross-section might be the same. In the latter case the air acts more directly, while in front of the large body there is formed a comparatively enormous "wedge" of more or less "dead" air, from which the air encountered flows off in but slightly inclined lines without transmitting the full pressure of its inertia. This fact, combined with the buoyancy of a gas vessel increasing with its size much faster than its resistance, and thus allowing it to carry with ease not only a strong internal framing, but also a motor of adequate power—170 horse-power—is responsible for the speed attained. Nine or ten passengers can be carried, besides sufficient ballast and fuel enough to take the ship on a round trip from Lake Constance to the farthest end of France and back again. Thus is removed the imaginary necessity for alighting on the water. With this system, an increase in size does not produce frailty any more than it does in one of the latest gigantic ocean

steamships, and it may be expected to result in such a gain in speed, radius of action and carrying capacity as to bring the transatlantic liner of the air almost in sight. In passing we may here mention the Wellman arctic balloon, a comparatively slow, but eminently practical and skilfully constructed air-craft.

So the present day is as yet that of the air-ship proper. The aëroplane, with its greater possibilities of speed, economy and practical usefulness is still hidden below the horizon, in spite of the tremendous impetus the Wright Brothers and Santos-Dumont has given to its advancement.

Santos-Dumont's was the first entirely public demonstration of man-flight without gas support—some 300 yards. The features of his machine which have gained for him a measure of success over many rivals, whom he did not far surpass in that American monopoly: aërodromical science, seem to have been the result of the same happy practical instinct which made his balloons famous.

There is a motor of excessive power, no transmission to get out of order, a simple, convenient, directly-driven, small propeller, out of harm's way in the rear, a large and highly efficient rudder working at the end of a long lever arm in the undisturbed air in front, and an accumulation and exaggeration of devices for preserving the lateral equilibrium, such as dihedral angle of superposed surfaces, and of a multiplicity of "keels," which might be called "barbarian" if compared to American moderation, though it exists to some extent in other French designs. The result is not a natural,

or faultless, but a rather "forced," or "artificial," "critical," equilibrium.

We may yet mention man-lifting kites in this account of "practical air-craft." The structures of Dr. A. G. Bell are very remarkable for strength combined with extreme lightness, and a large extent of surface which makes the practical side of their flying ability more obvious than in any other apparatus. The "incidental" stability is just as advantageous. They are to be turned into low speed flying machines by adding motor and propeller. The same is to be done with Israel Ludlow's singularly direct attempt at solving the flying problem—large man-lifting kites. He has had a truly astonishing degree of success as to the nearly vertical position of the line or rope in spite of the great head resistance, due to inexpensive and strong, but somewhat primitive construction. He has also attained an almost perfect stability in a strong wind. It seemed for a time as if, propellers being set going just at the moment when the machine was perfectly poised high up in the blue, true flight must result from this bold taking of the bull by the horns and launching a man without further preliminaries directly into the upper air. The drawback is in the dangerous stresses produced by the wind on kites of such transcendent size, especially if the rope cannot yield and they are towed with a speed of their own; and there might be room for improvement in the method of operation.

In conclusion ought to be mentioned the valuable prizes which, as a consequence of all the wonderful results mentioned, have recently been offered for specified

performances of aërial vehicles. Let us therefore hope, in view of the excellent inventors at work at the present time, that the scope of this review may be extended at a speedily increasing rate in the near future.

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THE line between experiments, which have brought but incomplete success, and those which are included in the above account, is in several instances not very easily drawn. It would therefore seem worth while to mention here a few more names to complete the list: P. Pilcher, in England, is an "understudy" of Lilienthal —to the extent of sharing the latter's tragic fate. J. J. Montgomery, in California, was the first to launch a gliding machine, with following surfaces at a high elevation from a balloon. He met with some initial success and a final catastrophe. H. F. Phillips in England, made a large and heavy steam-driven model lift itself from the ground, though not in free flight. M. C. Ader in France, at the expense of the government, repeated Maxim's feats in aërial steam engineering, and thus succeeded in making a man-carrying machine, of "impossible" design, lift itself for a few seconds from the ground. A. L. Hargrave in Australia made the first engine-driven models of fairly large size, but of primitive design, which were capable of sustained free flight.

NAVIGATING THE AIR

I

THE WRIGHT BROTHERS' MOTOR FLYER

By O. Chanute

THE flights of their first motor machine were made by Wright Brothers December 17, 1903, on their practice ground near Kitty Hawk, North Carolina. In 1904, having built a new machine, with such modifications as had been suggested by the practice of the previous year, they resumed their experiments near their home at Dayton, Ohio, in order to be close to their machine-shop and to repair promptly the breakages which they expected. They arranged with the local press not to notice them in any way.

That year they made 105 landings, each of which taught something, and some of which resulted in breakages. It was September before they succeeded in changing the course from one dead against the wind to a curved path, where cross currents must be encountered. A number of circular flights were then made, the two longest being nearly three miles each in about five minutes. Ballast was carried in these, first of fifty pounds and then of seventy pounds of iron bars, and the season's work was brought to a close in December.

In 1905 again was a new machine built to embody the changes which experience had dictated, and to test a new method of control. The experiments were resumed near Dayton about eight miles from the city. That year forty-nine flights were made, seven of which resulted in breakages of the machine without any personal accidents. September had come, however, before flights of more than ten miles had been accomplished. Then followed in rapid succession flights of eleven miles, twelve miles, fifteen miles, twenty-one miles and twenty-four miles. The last consisted of thirty sweeps over the course, and it was brought to a close by the exhaustion of the fuel of which but a small quantity had been carried.

By this time public gossip became irrepressible, spectators began coming to the scene of action, and the Wright Brothers, in order to preserve their secrets, abruptly terminated their flights and eventually dismantled their machine.

During the year 1906, they made no flights, as they were negotiating with intending purchasers, who enjoined secrecy. It is understood that they are prepared to give convincing demonstrations, as soon as their terms and conditions are accepted.

The fame of their achievements naturally spurred flying machine inventors all over the world to emulate their success. During the year 1906 more than a score of flying machines have been built and given preliminary tests, some in public, some in private. The greatest activity has been in France. M. Archdeacon, Captain Ferber, M. Vuia, M. Blériot, M. Voisin, M.

Esnault-Pelterie, M. Delagarde and Cornu & Son are known to have tested full-sized machines, and M. Tatin as well as Barlatier and Blanc, M. Solirène, M. Bazin, and M. Kapferer, have begun work on such apparatus; also M. Schelies, in Germany, and M. Ellehammer, in Denmark. They have all been distanced by M. Santos-Dumont who succeeded on November 12, 1906, in flying 220 meters in the presence of a large assemblage, thus improving his previous achievement of October 23, when he flew a distance of 60 meters against the wind. He has not yet swept a circle and this he must do to win the Archdeacon and Deutsch prize of 50,000 francs which requires a closed circuit of one kilometer in length. He is now hardly as far advanced as the Wright Brothers were at the close of 1903, and it is to be hoped that in his future experiments he will enjoy the same immunity from accident that they did.

II

THE RELATIONS OF WEIGHT, SPEED, AND POWER OF FLYERS

BY WILBUR AND ORVILLE WRIGHT

THE flyer of 1903 carried a four-cylinder gasolene motor of four-inch bore and four-inch stroke. Complete with magneto, radiators, tanks, water, fuel, etc., the motor weighed a little over 200 lbs.; and at 1200 revolutions per minute, developed 16 horse-power for the first 15 seconds after starting. After a minute or two the power did not exceed 13 to 14 horse-power. At 1020 revolutions per minute—the speed of the motor in the flights at Kitty Hawk on the 17th of December, 1903,—it developed about 12 horse-power.

The flyer of 1904 was equipped with a motor similar to the first, but of 1/8 inch larger bore. This engine at 1500 revolutions per minute developed 24 horse-power for the first 15 seconds, but only 16 to 17 horse-power after a few minutes' run. Complete with water, fuel, and other accessories, it weighed 240 lbs.

The same engine, with a few modifications in the oiling device and the carbureter, was used in all the flights of 1905. A test of its power made soon after the flights of October, 1905, revealed a gain of 3 horse-

power over tests made just before mounting it on the flyer in 1904. This gain is attributed to the increased smoothness of the cylinders and pistons produced by wear. The small output of these engines was due to lack of experience in building gasolene motors.

During the past year further improvements have been made, and our latest engines of four-inch bore and four-inch stroke produce about 25 horse-power continuously. The improvement in the reliability of the motor has been even more marked, so that now flights of long distances can be attempted without danger of failure on account of the stopping of the motor.

A comparison of the flyers of 1903, 1904, and 1905 shows some interesting facts. The flyer of 1903 weighed, complete with operator, 745 lbs. Its longest flight was of 59 seconds' duration with a speed of 30 miles an hour and an expenditure of 12 horse-power. The flyer of 1904 weighed about 900 lbs., including a load of 70 lbs. in iron bars. A speed of more than 34 miles an hour was maintained for a distance of 3 miles with an expenditure of 17 horse-power. The flyer of 1905 weighed, including load, 925 lbs. With an expenditure of 19 to 20 horse-power it traveled over 24 miles at a speed of more than 38 miles an hour. The flights of 1904 and 1905 would have been slightly faster had they been made in a straight line, as were those of 1903.

In 1903, 62 lbs. per horse-power were carried at a speed of 30 miles an hour; in 1904, 53 lbs. at 34 miles an hour; and in 1905, 46 lbs. at 38 miles an hour. It will be noticed that the weight carried per horse-power

is almost exactly in inverse ratio to the speed, as theory demands—the higher the speed, the smaller the weight carried per horse-power.

Since flyers can be built with approximately the same dynamic efficiency for all speeds up to 60 miles an hour, a flyer designed to carry a total weight of 745 lbs. at 20 miles an hour would require only 8 horse-power, or two-thirds of the power necessary for 30 miles an hour. At 60 miles 24 horse-power would be necessary—twice that required to carry the same weight at 30 miles an hour. At 120 miles an hour 60 to 75 horse-power would probably be necessary, and the weight carried per horse-power would be only 10 or 12 lbs. At such high speed the resistance of the operator's body and the engine is a formidable factor, consuming 64 times as much horse-power as at 30 miles an hour. At speeds below 60 miles an hour this resistance is almost negligible.

It is evident that the limits of speed have not as yet been closely approached in the flyers already built, and that in the matter of distance, the possibilities are even more encouraging. Even in the existing state of the art it is easy to design a practical and durable flyer that will carry an operator and supplies of fuel for a flight of over 500 miles at a speed of 50 miles an hour.

Dayton, Ohio, December 7, 1906.

"Aëro Club of America,
New York City, N. Y.

"*My dear sir:*

"In response to your request of November 21, I take

pleasure in telling of my observance of the Wright Brothers' aëroplane.

Early in October, 1905, it was my privilege to witness a very successful flight made by Mr. Wilbur Wright in the aëroplane of their own invention. When I arrived at the appointed place, the air-ship had already ascended and was flying at what seemed to me to be a distance of fifty feet from the ground, and in a rectangular course. That is, the operator was going first north, then west, then south, and then east, guiding and controlling his machine at will.

"A distance of twenty-four miles was covered on this occasion, in about thirty-eight minutes. The turns at the various corners of the field in which the flight was made, were made easily and gracefully, and it seemed to be as easy for Mr. Wright to operate it as for any one else to ride a bicycle. When the machine came to earth at the end of the flight it did so with a gliding motion, giving no perceptible jar or jolt to the operator. I believe that the aeroplane of the Wright Brothers has successfully solved the problem of aërial navigation.

"Very truly yours,

"E. W. Ellis,

"Assistant City Auditor."

Dayton, O., December 5, 1906.

"Aero Club of America.

"Gentlemen:

"In reply to your inquiry of recent date, I would state that I witnessed a flight of the Wright Brothers' aëroplane and there exists in my mind no doubt that, to the Wright Brothers is due the credit of the solution of aërial navigation without the aid of balloons or like contrivance.

"The day I witnessed their flight the aëroplane remained in the air at a height of between 50 to 100 feet for a period of about 23 minutes, and in that time covered a distance of about 15 miles, according to the meter attached to the aëroplane.

"The machine appeared at all times to be under perfect control, the operator elevating and lowering it at will. In his flight he described a circle of about a mile in circumference. Unfortunately, however, he was obliged to descend on account of a hot bearing.

"To an observer the machine resembles a huge bird in flight, and to me was the most inspiring sight that I have ever witnessed.

"Yours very truly,

"HOWARD M. MEYERS."

Dayton, Ohio, November 25, 1906.

"AERO CLUB OF AMERICA,
New York City.

"Dear Sir:

"The brothers, Wilbur and Orville Wright, have lived from childhood within a few squares of my home and have always had the fullest confidence of all their neighbors and acquaintance; but I must confess that when I read that they had solved the problem of human flight down on the coast of North Carolina I did not believe it. I thought that what they had accomplished was not real flight at all, but due to some peculiar condition of the atmosphere in that locality. I believed mechanical flight as impossible as perpetual motion.

"It was not until I saw one of their flights, near Dayton, with my own eyes that every doubt was removed.

"I was on the grounds and stood within a few feet of the machine while preparations were being made for the flight. I saw the machine start on the track upon

which it acquired initial speed, and I watched it as it gradually rose higher and higher in the air.

"I simply cannot describe my feelings during the first few minutes. When it was well above the tree-tops it continued on a level course in easy circles about the field, for more than half an hour, as timed by several spectators present.

"The operator brought it to the ground, without any damage whatever, directly in front of the building in which it was housed. I had seen the eighth wonder of the world!

"Respectfully yours,

"HENRY WEBBERS."

Dayton, Ohio, November 24, 1906.

"AERO CLUB OF AMERICA,
New York.

"Dear Sir:

"I take great pleasure in answering your letter of November 21, 1906.

"Along with some friends, I had the privilege of witnessing a flight of the Wright Brothers, in the autumn of 1905, a few miles east of Dayton. The machine started from a short track lying on the ground, and rose into the air on an inclined path till it was well above the height of the tallest trees. It then kept on a horizontal path flying round and round the meadow in circles about a quarter of a mile in diameter.

"The flight lasted more than a half hour. At last Mr. Orville Wright shut off the power and landed as gracefully as a bird just in front of the building in which the machine was kept.

"I can only say that it was the most wonderful sight of all my life. I was astonished to see farmers, driving home from the city, stop and watch the flight for

ten or fifteen minutes, and then drive on again; but I suppose they lived near-by and had seen the machine in flight many times before.

"Yours respectfully,

"CHAS. WEBBERT."

III

A FEW NOTES OF PROGRESS IN THE CONSTRUCTION OF AN AËRODROME[1]

By Dr. Alexander Graham Bell

FOR many years past the subject of aërial flight has had a great fascination for me; and in 1896, the sight of Langley's steam aërodrome circling in the sky, convinced me that the age of the flying machine was at hand.

I therefore quietly worked away at the subject in my Nova Scotia laboratory in the hope that I, too, might be able to contribute something of value to the world's knowledge on this important subject.

Warned by the experiences of others, I have sought for a safe method of approach—a method that should risk human life as little as possible during the earlier stages of experiment.

Experiments with aërodromes must necessarily be fraught with danger, until man, by practical experience of the conditions to be met with in the air, and of the means of overcoming them, shall have attained skill in the control of aërial apparatus.

[1] An extract from an address upon "Aërial Locomotion," delivered before the Washington Academy of Sciences, December 13, 1906.

A man cannot even ride a bicycle without practice; and the birds themselves have to learn to fly.

Man, not having any inherited instincts to help him in this matter, must first control his flight consciously, guided by knowledge gained through experiment.

Skill can only be obtained by actual experience in the air; and this experience will involve accidents and disasters of various sorts before skill can be obtained.

If these disasters should, as so often in the past, prove fatal to the experimenter, skill cannot be gained. The knowledge obtained by the would-be aviator will then be lost to the world; and others must begin all over again instead of pursuing the subject where he left off, with the benefit of his knowledge and his experience.

It is, therefore, of the utmost consequence to progress in the art of aviation, that the first attempts to gain experience in the air, should be made under such conditions of safety as to reduce to a minimum the liability to fatal results.

The Wright Brothers' successful flying-machine travels at the rate of about 37 miles an hour; and judging from its great flying weight (nearly 2 lbs. per square foot of supporting surface), it is unlikely that it could be maintained in the air if it had a very much less velocity. But should an accident happen to a body propelled through the air with the velocity of a railroad train, how about the safety of the occupants? Accidents will happen, sooner or later, and the chances are largely in favor of the first accident being the last experiment.

While, therefore, we may look forward with confidence to the ultimate possession of flying-machines exceeding in speed the fastest railroad trains, it might be the part of wisdom to begin our first experiments at gaining experience in the air, with machines traveling at such moderate velocities, and at such moderate elevations, as to reduce the chances of a fatal catastrophe to a minimum. This means that they should be light flying-machines; that is, the ratio of weight to supporting surface should be small.

While theory indicates that the greater the weight in proportion to supporting surface consistent with flight the more independent of the wind will the machine be, yet it might be advisable to begin, if possible, with such a moderate flying weight as to permit of the machine being flown as a kite. There would be little difficulty then in raising it into the air; and, should an accident occur to the propelling apparatus, the machine would descend gently to the ground; or the aviator could cast anchor, and his machine would continue flying as a kite.

One of the chief causes that have led to disasters in the past has been a lack of stability in the air. Automatic stability under varying conditions is of the very first consequence to safety; for what would it profit a man were he to gain the whole world and lose his own equilibrium in the air?

It occurred to me that the question of equilibrium could most safely be studied by constructing an aërial vehicle that could be flown as a kite: it would follow as a matter of course that, if propelled through calm

air with the velocity of the wind that supported it as a kite, the machine would also be supported in the air as a free flying-machine.

On two previous occasions I have presented communications to the National Academy of Sciences relating to experiments with kites. The first was on "Kites with Radial Wings" presented April, 1899; and reviewed with illustrations, in the "Monthly Weather Review" for April, 1899 (Vol. XXVI, pp. 154–155, Plate XI).

The second was upon "The Tetrahedral Principle in Kite Structure" presented April 23, 1903; and published, with ninety-one illustrations and an Appendix, in the "National Geographic Magazine" for June, 1903 (Vol. XIV, pp. 220–251).

The experiments referred to, which were undertaken at first for my own pleasure and amusement, have gradually assumed a serious character from their bearing upon the flying-machine problem.

The word "kite," unfortunately, is suggestive to most minds of a toy—just as the telephone at first was thought to be a toy—so that the word does not at all adequately express the nature of the enormous flying structures employed in some of my experiments. These structures were really aërial vehicles rather than kites, for they were capable of lifting men and heavy weights into the air. They were flown after the manner of kites, but their flying-cords were stout manila ropes. They could not be held by hand in a heavy breeze, but had to be anchored to the ground by several turns of the ropes around stout cleats like those employed on steamships and men-of-war.

One of the great difficulties in making a large structure light enough to be flown as a kite, has been pointed out by Prof. Simon Newcomb in an article in "McClure's Magazine" published in September, 1901, entitled "Is the Air-ship Coming?"; and this difficulty had so much weight with him at that time, as to lead him to the general conclusion that "the construction of an aërial vehicle which could carry even a single man from place to place at pleasure, requires the discovery of some new metal, or some new force."

This conclusion, the Wright Brothers, and now Santos-Dumont, have demonstrated to be incorrect; but Prof. Newcomb's objections undoubtedly have great force; and reveal the cause of the failures of attempts to construct large-sized flying-machines upon the basis of smaller models that actually flew.

Prof. Newcomb shows that where two aërial vehicles are made exactly alike, only differing in the scale of their dimensions, the ratio of weight to supporting surface is greater in the larger one than in the smaller,—the weight increasing as the cube of the dimensions, whereas the supporting surfaces only increase as the squares.

From this the conclusion is obvious that if we make our structure large enough, it will be too heavy to fly—even by itself—far less be the means of supporting an additional load like a man, and an engine for motive power. This conclusion is undoubtedly correct in the case of structures that are "exactly alike, excepting in their dimensions"; but it is not true as a general proposition.

A small bird could not sustain a heavy load in the

air; and while it is true that a similar bird of double the dimensions would be able to carry a less proportionate weight because it is itself heavier in proportion to its wing surface than the smaller bird—eight times as heavy in fact, with only four times the wing surface—still it is conceivable that a flock of small birds could sustain a heavy load divided equally among them, and it is obvious that in this case the ratio of weight to wing surface would be the same for the whole flock as for the individual bird.

If, then, we build our large structure by combining together a number of small structures each light enough to fly; instead of simply copying the small structure upon a larger scale, we arrive at a compound or cellular structure in which the ratio of weight to supporting surface is the same as that of the individual units of which it is composed, thus overcoming entirely the really valid objections of Prof. Newcomb to the construction of large flying machines.

In my paper upon the tetrahedral principle in kite structure, I have shown that a framework having the form of a tetrahedron possesses in a remarkable degree the properties of strength and lightness. This is especially the case when we adopt as our unit structure the form of the regular tetrahedron, in which the skeleton frame is composed of six rods of equal length, as this form seems to give the maximum of strength with the minimum of material. When these tetrahedral frames or cells are connected together by their corners they compose a structure of remarkable rigidity, even when made of light and fragile material—the

whole structure possessing the same properties of strength and lightness inherent in the individual cells themselves.

The unit tetrahedral cell yields the skeleton form of a solid, and it is bounded by four equal triangular faces. By covering two adjoining faces with silk, or other material suitable for use in kites, we arrive at the unit "Winged Cell" of the compound kite; the two triangular surfaces, in their flying position, resembling a pair of wings raised with their points upward—the surfaces forming a dihedral angle.

Four of these unit cells, connected together at their corners, form a four-celled structure having itself the form of a tetrahedron, containing in the middle an empty space of octahedral form, equal in volume to the four tetrahedral cells themselves. In my paper, I showed that four of these four-celled structures connected at their corners resulted in a sixteen-celled structure of tetrahedral form, containing, in addition to the octahedral spaces between the unit cells, a large central space equivalent in volume to four of the four-celled structures.

In a similar manner four of the sixteen-celled structures connected together at their corners form a sixty-four-celled structure; four of the sixty-four-celled structures form a two-hundred-and-fifty-six-celled structure, etc., etc.; and in each of these cases an empty space exists in the center, equivalent to half of the cubical contents of the whole structure, in addition to spaces between the individual cells, and minor groups of cells.

Kites so formed, exhibit remarkable stability in the air under varying conditions of wind, and I stated in my paper that the kites which had the largest central spaces seemed to be the most stable in the air. Of course these were the structures that were composed of the largest number of unit cells, and I now have reason to believe that the automatic stability of these kites depends more upon the number of unit cells than upon the presence of large empty spaces in the kites; for I have found, upon filling in these empty spaces with unit cells, that the flying qualities of a large kite have been greatly improved.

The structure, so modified, seems to fly in as light a breeze as before, but with greatly increased lifting power; while the gain in structural strength is enormous. I had hitherto supposed that if cells were placed directly behind one another, without providing large spaces between them, comparable to the space between the two cells of a Hargrave box-kite, the front cells would shield the others from the action of the wind, and thus cause them to lose their efficiency; but no very marked effect of this kind has been observed in practice. Whatever theoretical interferences there may be, the detrimental effect upon the flying qualities of a kite are not, practically, obvious; while the gain in structural strength and in lifting power outweighs any disadvantages that may exist. I presume that there must be some limit to the number of cells that can be placed in close proximity to one another without detrimental effect, but so far my experiments have not revealed it.

To test the matter, I put together into one structure

all the available cells I had in the laboratory—1300 in number. These were closely attached together without any other empty spaces in the structure than those existing between the individual cells themselves when in contact at their corners. The resulting kite, known as the *Frost King*, consisted of successive layers, or strata of cells, closely superposed upon one another. The lowest layer, or floor of the structure, consisted of 12 rows of 13 cells each. The cells forming each row were placed side by side attached to one another by their upper corners; and the 12 rows were placed one behind the other, the rear corners of one row being attached to the front corners of the row immediately behind. The next stratum above the floor had 11 rows of 14 cells; the next, 10 rows of 15 cells, etc.; each successive layer increasing in lateral dimensions and diminishing in the fore and aft direction; so that the top layer, or roof, consisted of a single row of 24 cells placed side by side.

One would imagine that a closely-packed mass of cells of this kind—1300 in number—would have developed some difficulty in flying in a moderate breeze if the cells interfered with one another to any material extent; but this kite not only flew well in a breeze estimated at not more than about 10 miles an hour because it did not raise white caps, but carried up a rope-ladder, several dangling ropes 10 or 12 meters long, and more than 200 meters of Manila rope used as flying lines, and, in addition to all this, supported a man in the air.

The whole kite, impedimenta and all, including the man, weighed about 131 kilograms (288 lbs.); and its

greatest length from side to side was 6 meters at the top and 3 meters at the bottom. The sloping sides measured 3 meters, and the length from fore to aft at the square bottom was 3 meters.

It is obvious that this kite might be extended laterally at the top to twice its length without forming an immoderately large structure. It would then be 12 meters on the top (39 ft.), and 9 meters on the bottom from side to side, without changing the fore and aft dimensions, or the height. It would then contain more than double the number of cells, and so should be able to sustain in the air more than double the load; so that such a structure would be quite capable of sustaining both a man, and an engine of the weight of a man, and yet be able to fly as a kite in a breeze no stronger than that which supported the *Frost King.*

An engine of the weight of a man could certainly impart to the structure a velocity of 10 miles an hour, the estimated velocity of the supporting wind, and thus convert the kite into a free flying-machine.

The low speed at which I have been aiming—for safety's sake—is therefore practicable.

In the *Frost King* and other kites composed exclusively of tetrahedral winged cells, there are no horizontal surfaces (or rather surfaces *substantially* horizontal as in ordinary kites), but the framework is admirably adapted for the support of such surfaces. Horizontal aëroplanes have much greater lifting power than similar surfaces obliquely arranged, as in the tetrahedral construction, and I have made many experiments to combine horizontal surfaces with winged

cells with greatly improved results so far as lifting power is concerned. But there is always an element of instability in a horizontal aëroplane, especially if it is of large size; whereas kites composed exclusively of winged cells are wonderfully steady in the air under varying conditions, though deficient in lifting power; and the kites composed of the largest number of winged cells seem to be most stable in the air.

In the case of an aëroplane of any kind the center of air pressure rarely coincides with the geometrical center of surface, but is usually nearer the front edge than the middle. It is liable to shift its position at the most unexpected times on account of some change in the inclination of the surface or the direction of the wind. The change is usually small in steady winds; but in unsteady winds great and sudden changes often occur. The extreme possible range of fluctuation is, of course, from the extreme front of the aëroplane to the rear, or *vice versa;* and the possible amount of change, therefore, depends upon the *dimensions* of the aëroplane—especially in the fore and aft direction. With a large aëroplane the center of pressure may suddenly change to such an extent as to endanger the equilibrium of the whole machine. Whereas, with smaller aëroplanes, especially those having slight extension in the fore and aft direction, the change, though proportionately as great, is small in absolute amount. Where we have a multitude of small surfaces well separated from one another, as in the tetrahedral construction, it is probable that the resultant center of pressure for the whole kite can shift to no greater extent than

the centers of pressure of the individual surfaces themselves. It is, therefore, extremely unlikely that the equilibrium of a large kite could be endangered by the shifting of the centers of pressure in small surfaces within the kite. This may be the cause of the automatic stability of large structures built of small tetrahedral cells. If so, one principle of stability would be: *small surfaces, well separated, and many of them.*

The converse proposition would then hold true if we desired to produce instability and a tendency to upset in a squall, viz.: *large surfaces, continuous, and few of them.*

Another source of danger with large continuous surfaces is the fact that a sudden squall may strike the kite on one side, lifting it up at that side and tending to upset it. But the compound tetrahedral structure is so *porous* that a squall passes right through and lifts the *other side* as well as the side first struck; so that the kite has not time to be upset before the blow on one side is counterbalanced by a blow on the other. I have flown a Hargrave box-kite simultaneously with a large kite of many tetrahedral cells in squally weather for the purpose of comparing them under similar circumstances. The tetrahedral structure often seemed to shiver when struck by a sudden squall, whereas the box-kite seemed to be liable to a swaying or tipping motion that would be exceedingly dangerous in a structure of large size forming part of a flying-machine.

Another element of stability in the tetrahedral structure lies in the fact that the winged surfaces are elevated at a greater angle above the horizon than 45°.

Supposing the wings of a cell to be opened out until they are nearly flat—or at least until they each make a comparatively small angle with the horizon—say 20° —then if, from any cause, the cell should tip so as to elevate one wing (say to 25°) and depress the other (say to 15°)—then the lifting power of the wind will be increased upon the elevated wing and diminished on the depressed wing, so that there would be no tendency to a recovery of position, but the very reverse, the pressure of the wind would tend to increase the tipping action, and favor the production of oscillation and a tendency to upset; for the lifting action of the wind upon a surface inclined at 10° would be less than at 20°, and greater at 25° than 20°. The more the wings are opened out and the flatter they become, the more essentially unstable is the arrangement in the air.

Now, suppose the wings to be raised until they are nearly closed—or at all events until they make a small angle with the vertical (say 70° from the horizontal), —then if from any cause the cell should tip so as to elevate one wing (say to 75°) and depress the other (say to 65°)—the lifting power of the wind will be increased upon the *depressed* wing, and diminished on the elevated wing; for the lifting force of the wind is greater at 65° than at 70° and less at 75°. Thus, the moment a tipping action begins, the pressure of the wind resists it; and an active force is involved tending to restore the structure to its normal position. The more the wings are raised, and the more they approach the perpendicular position, the more stable essentially is the arrangement in the air.

The dividing line between these two opposite conditions seems to be drawn about the angle of 45°—and as the tetrahedral wing surfaces make a greater angle than this with the horizontal, they constitute an essentially stable arrangement in the air; whereas a horizontal surface represents the extreme of the undesirable unstable condition.

These considerations have led me to prefer a structure composed of winged tetrahedral cells alone, without horizontal surfaces either large or small, although the lifting power is less than when horizontal surfaces are employed—because the factor of *safety* is greater. Equilibrium is of the first consequence, and if the lifting power is sufficient for our purpose, there is no necessity for introducing a factor of danger by the addition of horizontal surfaces. Of course the addition of horizontal surfaces would enable us to secure the desired lifting power with a smaller and therefore lighter structure—and this would be an advantage if we could be sure of perfect stability in the air. In employing the hollow construction with tetrahedral cells—in which large empty spaces occurred, a great difficulty was encountered consisting in the enormous size of the structure required to support a man, combined with the increasing weakness of the structure as it increased in size. The discovery that the cells may be closely massed together without marked injurious effects has completely remedied this difficulty; for not only is the structural strength improved by an increase of size, but the lifting power increases with the *cube* of the dimensions; so that a very

slight increase in the dimensions of a large kite increases very greatly its lifting power. We now have the possibility of building structures composed exclusively of tetrahedral winged cells that will support a man and an engine, in a breeze of moderate velocity, without the necessity of constructing a kite of immoderate size. The experiments with the *Frost King* made in December, 1905, satisfied me upon this point, and brought to a close my experiments with kites.

CONCLUSION

SINCE December, 1905, my attention has been directed to other points necessary to be considered before an aërodrome of the kite variety could be made; and to the assembling of the materials for its manufacture.

I have had to improve and simplify the methods of making the winged cells themselves. Through the agency of Mr. Hector McNeil, superintendent of the Volta Laboratory, Washington, D. C., who is now taking up the manufacture of tetrahedral cells as a new business, I am now able to obtain cells constructed largely by machinery, and with stamped-metal corners to hold the rods together. The process of tying the cells and parts of cells together had proved to be very laborious and expensive; and the process was not suited to unskilled persons. By the new process most of the work is done by machinery, and no skill is required to connect the cells together.

I have also had to go into the question of motor construction, a subject with which I am not familiar; and

while waiting for the completion of the material required for the aërodrome, I have been carrying on experiments to test the relative efficiency of various forms of aërial propellers. I have also been occupied with the details of construction of the proposed aërodrome, and the consideration of the safest method of launching it into the air, and bringing it down safely. Of course it would be premature for me to enter into any description of experiments that are still in progress, or to submit plans for an aërodrome which are still under discussion. I shall, therefore, simply say in conclusion that I have recently been making experiments in propelling, by means of aërial propellers, a life-raft supported, catamaran fashion, on two metallic cylinders.

The whole arrangement, with a marine motor on board, is exceedingly heavy, weighing over 2500 lbs., and it is sunk so low, that the water level rises at least to the middle of the supporting cylinders, so that the raft is not at all adapted for propulsion, and cannot attain great speed. The great and unnecessary weight of this machine has led to an interesting and perhaps important discovery that might have escaped attention had the apparatus been lighter and better adapted for propulsion.

Under the action of her aërial propellers, this clumsy raft is unable to attain a higher speed than four miles an hour; and yet she is able to face a sixteen-mile white-cap breeze, and make headway against it, instead of drifting backward with the wind.

Of course there would be nothing remarkable about this if her propellers were acting in the water instead

of the air, but they are not. They act exclusively in the air, and the water is only an additional resistance to be overcome.

The explanation probably lies in the enormous mass of the moving body which enables it to acquire very considerable momentum with slight velocity; whereas, the opposing current of air has such slight mass that it cannot acquire an equal momentum with a very much higher velocity.

The suggestiveness of this result lies in its application to the flying machine problem. A balloon, on account of its slight specific gravity, must ever be at the mercy of the wind. In order to make any headway against a current of air it must itself acquire a velocity superior to the wind that opposes it. Not so, however, with the flying machine heavier than the air.

If two bodies of unequal mass, moving with equal but opposite velocity, come into collision with each other, then the heavier body will not be completely stopped by the lighter; it will make headway against the resistance of the other, even though the lighter should possess superior velocity, provided, of course, that it has a sufficient superiority of mass. We are dealing here with *momentum,* not velocity alone. The body having the greatest momentum will be the victor in the struggle, whatever the relative velocities may be.

A free flying machine of the heavier-than-air variety then, at whatever speed it moves, will be able to make headway against a wind of far greater velocity, provided its momentum is greater than the momentum of the air that opposes it.

APPENDIX

Details Concerning the Kite *Frost King*

Number of cells in the "Frost King"

Layer of cells	No. of rows	No. of cells in each row	No. of cells in each layer
1st layer	1	24	24
2d layer	2	23	46
3d layer	3	22	66
4th layer	4	21	84
5th layer	5	20	100
6th layer	6	19	114
7th layer	7	18	126
8th layer	8	17	136
9th layer	9	16	144
10th layer	10	15	150
11th layer	11	14	154
12th layer	12	13	156
		Total number of cells	1300

Dimensions: Each cell has a side of 25 centimeters, so that the roof, or ridge-pole, measured 6 meters extending laterally across the top of the structure. The oblique sides were 3 meters in length; and the bottom, or floor, formed a square having a side of 3 meters. The whole structure constituted a section of a tetrahedral kite—the upper half, in fact, of a kite, having the form of a regular tetrahedron with a side of 6 meters.

Weight: The winged cells composing this structure weighed on the average 13.84 gms. apiece, so that the

whole cellular part of the structure which supported all the rest—consisting of 1300 winged cells—weighed 17,992 gms.

In addition to this, the kite carried as dead load stout sticks of wood which were run through the structure to distribute the strain of the pull upon the strong parts of the framework, that is, upon the junction points of the cells. The outside edge of the kite was also protected by a beading of wood. The whole strengthening material weighed 9702 gms., and the kite as a whole weighed 27,694 gms. (61 lbs.).

Surface: I estimate the surface of an equilateral triangle having a side of 25 centimeters, as about 270.75 square centimeters; in which case the silk surface of a single winged cell, consisting of two triangles, amounts to 541.5 square centimeters, and the actual silk surface employed in 1300 cells equals 70.3950 square meters (757.7 sq. ft.).

These surfaces are all oblique; and if we resolve the oblique surfaces into horizontal and vertical equivalents (supporting surfaces and steadying surfaces) we find that the resolved horizontal equivalent (supporting surface) of a single winged cell forms a square of which the diagonal measures 25 centimeters, and this is equivalent to a rectangular parallelogram of 25x12.5 cm., having an area of 312.5 square centimeters.

Thus an actual silk surface of 541.5 square centimeters, arranged as the two wings of a winged cell, yields a supporting surface of 312.5 square centimeters.

In kites, therefore, composed exclusively of tetrahedral winged cells, each having a side of 25 centimeters,

the area of supporting surface bears the same proportion to the actual surface as the numbers 3125 to 5415; or 1 to 1.7328.

$$\frac{\text{Supporting Surface}}{\text{Actual Surface}} = \frac{1}{1.7328}$$

A simple way of calculating the amount of supporting surface in such structures is to remember that there are 32 cells to the square meter of supporting surface. Therefore, the 1300 cells of the kite *Frost King* had a supporting surface of 40.6250 square meters (437.3 sq. ft.).

Ratio of weight to surface: The actual silk surface employed in the *Frost King* was 70.3950 square meters (757.7 sq. ft.), the weight of the kite was 27,694 gms. (61 lbs.), so that on the basis of the actual surface, the flying weight was 393.4 gms. per square meter (0.08 lbs. per sq. ft.).

But for the purpose of comparing the flying weight of a tetrahedral kite with that of other kites in which it is usual to estimate only the aëroplane surfaces that are substantially in a horizontal plane, it would be well to consider the ratio of weight to horizontal or supporting surface in this kite.

The weight was 27,694 gms. (61 lbs.); the resolved horizontal or supporting surface was equivalent to 40-.6250 square meters (437.3 sq. ft.), and the flying weight for comparison with other kites was 681.7 gms. per square meter of supporting surface (0.14 lbs. per sq. ft.).

The kite, in addition to its own weight, carried up a mass of dangling ropes and a rope-ladder, as well as two flying-cords of Manila rope. The impedimenta of this kind weighed 28,148 gms. (62 lbs.). It also supported a man, Mr. Neil McDermid, who hung on to the main flying-rope at such a distance from the cleat attached to the ground that when the rope straightened under the strain of the kite he was carried up into the air to a height of about 10 meters (over 30 ft.). The weight of this man was 74,910 gms. (about 165 lbs.). Thus, the total load carried by the kite, exclusive of its own weight, was 103,058 gms. (or 227 lbs.).

The whole kite, load and all, including the man, therefore, weighed 130,752 gms. (288 lbs.), and its flying weight was 1857.4 gms. per square meter of actual surface (0.38 lbs. per sq. ft.); or 3218.5 gms. per square meter of supporting surface (0.66 lbs. per sq. ft.)

IV

THE FIRST ANNUAL AËRONAUTIC CUP RACE[1]

BY LIEUT. FRANK P. LAHM.
Sixth Cavalry, U. S. Army

THE first annual contest for the aëronautic cup, offered by Mr. James Gordon Bennett, started from the Tuileries Gardens, in Paris, France, on September 30, 1906.

Sixteen balloons, representing seven different countries—the United States, Great Britain, France, Belgium, Germany, Italy, and Spain, were entered, and in spite of the difficulties due to time, distance and expense, every one of the sixteen started on the 30th, —truly a good record, and one seldom equaled in other sports.

Less than a year ago Mr. Bennett placed a cup in the hands of the Aero Club of France, which gladly assumed the responsibility for organizing the first of these contests. How well it acquitted itself of its task is attested by the success achieved at the Tuileries Gardens on the 30th of September. Sixteen balloons, requiring in all over a million cubic feet of gas, were

[1](By courtesy of the Journal of Military Service Institution)

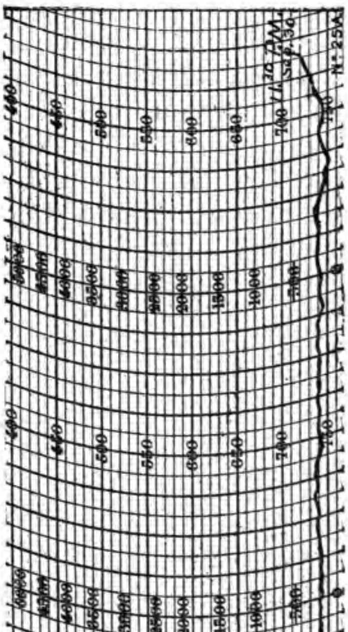
prepared, filled, and started off in the presence of 200,000 spectators, without a pause, without a hitch, exactly according to the published program.

The first balloon started at 4 P.M. Long before that time the gardens and the large Place de la Concorde adjoining were packed with a curious and interested crowd. Several bands were on hand to enliven the occasion. Countless numbers of small toy balloons, of inflated figures of men and animals made out of gold-beater's skin, were released during the hours preceding the start of the first balloon. Finally a flock of carrier pigeons was set free. All this, combined with the natural gaiety of a French holiday gathering, made a fascinating and long-to-be-remembered scene.

Lots had been drawn for the order of starting, and Signor Vonwiller of the Italian Club, drew first place. At exactly four o'clock, his beautiful silk balloon the *Elfe* rose slowly and gracefully from the starting-point beside the little pond at the upper end of the gardens. Passing over the Place de la Concorde, he started directly west. Then in their designated order and at five-minute intervals, followed the fifteen remaining balloons. None drew more applause than Santos-Dumont, who, true to his mechanical ingenuity, went up with a six-horse-power motor buzzing away, driving two horizontal propellers destined to give a vertical motion to his balloon, thus dispensing with his having to throw out ballast.

My balloon, the *United States,* representing the Aero Club of America, was the twelfth to start. My companion was Major Henry B. Hersey, of the Rough

No. 1



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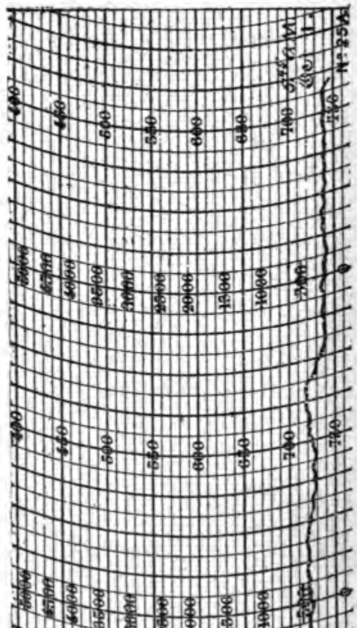

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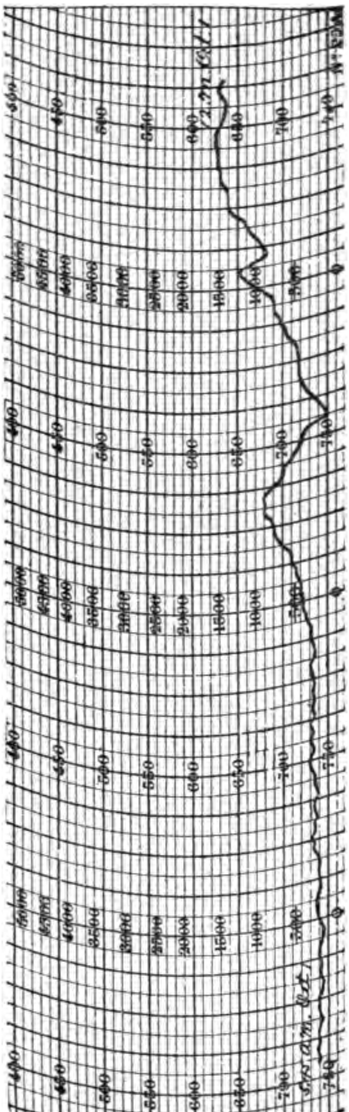
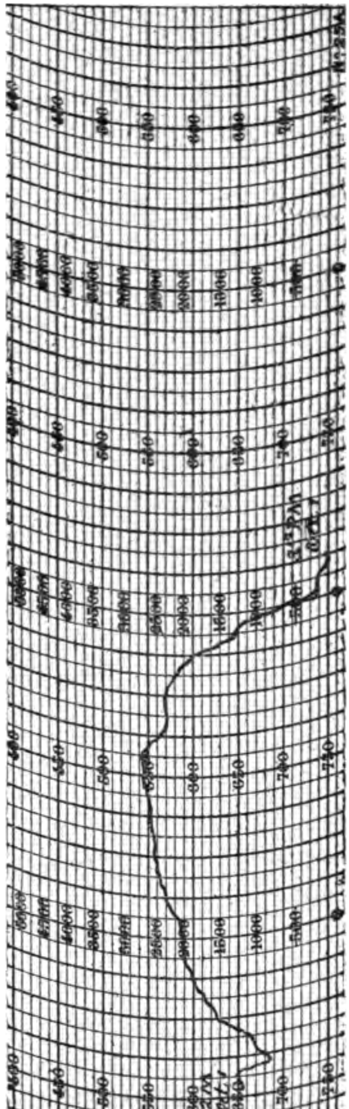


No. 4



Lahm Barogram of the balloon *United States*, during Gordon Bennett Cup Race.

Riders of '98, and at present chief executive of the Wellman Polar Expedition. We took our places in the car at 4:40, were "lead" to the starting-point by the squad of balloon soldiers especially detailed from the French balloon troops for that day, and at 4:55 we left the earth. Like all the preceding balloons we went directly west, following the Seine for a distance, passing the Eiffel Tower, across the Longchamps race-track, where the crowd was just breaking up after the races, across the Seine again at St. Cloud and out into the country, keeping at an altitude of 600 to 1200 feet. For the first two hours we had four other balloons quite near us. One from its yellow color we easily recognized as one of the three German balloons; another, from its elongated shape, we knew to be the English balloon *Brittania,* piloted by Mr. Rolls. As night came on they disappeared one by one, till finally at 9:30 P.M. all were lost to view.

As long as daylight lasted we had no trouble whatever in tracing our course on the maps we carried; but after dark this became more difficult, and we had to depend on the speaking trumpet. By calling down to the villagers we could make ourselves heard and generally received a reply. Before 11:00 we had passed over Lisieux, the 300-foot guide-rope just grazing the tops of the houses. By this time we had undergone a decided change of direction and were traveling northwest. It was evident before leaving Paris that we should strike the sea, so I had taken the precaution to carry along a dozen wooden hoops, about a foot in diameter, and as I emptied the first ballast bags of

their sand I tied a hoop in the mouth of each one, then attached a cord to the hoop. This contrivance is called a cone anchor, and is taken as a precaution if there is a chance of being carried out to sea. By trailing it in the water the progress of the balloon is retarded, thus giving a vessel an opportunity to overtake the balloon.

At seventeen minutes past 11 P.M. we slipped quietly out over the English Channel, the end of the guide-rope just off the water, and began the second and most interesting part of our trip. Our direction on reaching the Channel would have taken us out to the southwestern extremity of England, but again the wind veered and we were traveling west of north.

To describe the beauty of the Channel crossing would require the pen of a master. With a full moon shining overhead, an almost cloudless sky, the balmy air, and, except for the gentle breaking of the waves beneath us, not a sound to disturb the perfect calm, nothing could be more charming, nothing more delightful. With occasional reference to the compass and north star, we knew our direction was good, so had no uneasiness on that score. Sitting on the bottom of the car on the ballast bags, occasionally looking over to see if the guide-rope was clear of the water, if not, throwing out a scoopful of sand to send us up a few feet, we quietly ate our long-postponed dinner of sandwiches, chicken, eggs, fruit, coffee and other good things which we had laid in before starting. Once a little sailing vessel slipped under us and disappeared in the night. This was the only sign of life we saw in the Channel. The revolving light on the

coast at Havre was on our right at the start, but we soon left it behind.

At 2:30 A.M. a revolving light appeared ahead of us, and we knew we were approaching the English shore. On coming closer we were able to recognize that this light was on a light-ship. An hour later we were over the *terra firma* of old England. Soon afterward the lights of a large city appeared on our left. We knew this must be Chichester, in the county of Sussex.

Then the friendly moon deserted us, and heavy mists covered up the lowlands, so that we lost sight of the earth, catching only an occasional glimpse of the black tops of the trees under the end of the guide-rope. The first color of dawn showed itself in the east before five o'clock, but due to the mist and fog, it was past six before we were able to distinguish clearly the ground beneath us. We were forcibly impressed with the fact that the English farmer is not an early riser, for the loud and continued shouts of my companion did not bring forth a response till past seven. Then we learned that we had crossed the counties of Sussex and Hampshire in the fog, and were then over Berkshire.

All morning we journeyed up over England, past Warwick Castle, past Stratford-on-Avon. Then the warm sun came out, heating and expanding the gas in the balloon and carrying us higher and higher in the air.

At two o'clock in the afternoon we had reached an altitude of 10,000 feet. As we rose higher, our direction changed to east of north. From the direction of

clouds at a lower level than ourselves, and of the smoke at the ground, we knew that the lower currents of air would take us farther to the west, so we started down in the hope of being able to change our direction sufficiently to take us into Scotland. A few minutes more brought us to the brown and barren moors, and then the coast of the North Sea loomed up straight ahead of us. It was necessary to hasten the descent, so I opened the valve and allowed a good supply of gas to escape. Down we came until the guide-rope was trailing on the moors. We knew it was just a question of minutes until we should be at sea; but as the wind had changed slightly, we hoped to continue long enough to reach a more settled district, and possibly a railroad station. A few minutes more and we had reached the edge of the moors; then a little railroad appeared to the right, running along the coast. Another minute and a small station was in sight. A farm-house ahead looked inviting, so we decided to land. But I had overestimated the gripping power of my anchor, for on striking the ground it tore up a little sod, then let go, and the wind carried us on. A stone wall served only to twist the shank of the anchor.

Finally, due to the loss of gas, the car struck the ground in a field a half mile past the house, jumped up just high enough to clear a stone wall, came down again, turned on its side, dragged a few yards after the tugging balloon, then stopped. On striking the second time, I pulled the "rip cord" which tears a large strip out of the top of the balloon. The gas rushed out, and our good steed which had carried us so many

miles lost his strength and lay stretched out on the meadow, a flat and empty bag.

Before extricating myself from the ropes, ballast bags and other impediments, I looked at my watch—exactly 3 : 12 P.M. We had been in the air twenty-two hours and seventeen minutes, and according to the measurements of the committee, published since, we had covered over 647 kilometers, or about 410 miles, in a straight line from Paris. Necessarily, the actual distance traveled was considerably longer than this, as our course had not been a straight line at all.

Our reception by the goodly people of Fyling Dales (the name of the manor) was a most cordial one. The squire himself chanced to be in an adjoining field and hastened up to inquire if we were injured. The amazement of the tenants was amusing. As the squire said, "an earthquake could not have caused more excitement in the neighborhood than had the landing of our balloon."

With the cheerful assistance of willing hands, the *United States* was soon folded, packed on to a wagon, and we were off for the railroad station, a mile away. Fyling Hall was the name of the place, fifteen miles north of Scarborough, in the northern part of the county of York. In the immediate neighborhood, in fact, within sight of our landing-spot, were places with familiar and interesting names, such as the Convent of Whitby, and Robin Hood's Bay. Gladly would we have stopped a day or two in this quaint and attractive district, but we were drawn still more strongly toward London and news of the other balloons.

As neither of us had had a wink of sleep the night

before, we stopped at York for a night's rest. Next morning I was awakened by vigorous pounding on my door. "Wake up and look at this!" It was Major Hersey, and from the unusually cheery ring in his voice I suspected good news. The morning papers he brought did indeed report us as the winners, although they failed to account for Mr. Rolls of the English Club. On our arrival in London that afternoon all doubts were dispelled when we read the classing of the first four balloons in the following order: the *United States* first; Signor Vonwiller of the Italian Club, second, landing at Hull, some forty-five miles behind us; Mr. Rolls, third; and Count de La Vaulx, of the French Club, fourth. Nine of the sixteen balloons had not attempted the Channel crossing, but had landed on French soil.

In marked contrast was our crossing of the Channel that night on our return to Paris, with our beautiful crossing in the *United States* two nights before. A violent southwest wind made the little cross-Channel steamer perform as only those little steamers can, and made us wish regretfully for our aërial craft.

Our welcome in Paris was a most hearty one. First came the sleepless reporters, then our friends, the secretary of the French Club, then dozens of telegrams, cables and letters. The following evening the Aero Club gave a dinner, presided at by Prince Roland Bonaparte, president of the International Federation of Aero Clubs. After dinner we were treated to an exhibition of moving pictures of the start at the Tuileries, four days before.

To one who has never had the pleasure of a trip in

a balloon it may be interesting to know what we carried with us in the car. In the bottom was a layer of straw to keep us warm. This proved entirely unnecessary. About a third of the space was occupied at the start with the sand used for ballast. This was in twenty-nine sacks, weighing over forty pounds each. Our "navigating" instruments consisted of a registering barometer for telling the height above sea-level at any time; a statoscope, which records immediately an ascending or descending movement; two electric lamps for reading the instruments and maps at night (matches and fire of any kind are absolutely forbidden in a balloon, due to the danger of exploding the gas); numerous maps of France, England, Germany and even of all Europe, for a balloonist never knows exactly where the wind may take him; a compass, and a couple of life-preservers for use in case we dropped into the sea. The anchor, guide-rope and balloon cover were attached on the outside of the car. A dozen blank forms, to be thrown overboard at intervals, were intended to assist in tracing our course. Whoever picked them up was to fill in the time and place, and mail them to the Aero Club. Six of those I threw out were afterward received from different points in France and England. Extra cord, heavy clothing, provisions, including a patent bottle from which we were able to drink steaming hot coffee the following morning completed the equipment.

A tube of oxygen for use at high altitudes, where the air is rare, was left behind at the last minute, as we realized we should not have to go so far. A supply

of German money, which I had taken the precaution to procure the day before the race, was of no use, and we had to take advantage of the offer of the good English squire of Fyling Dales. He loaned us enough English money to take us to York, where we were able to change our French money.

The winning of the cup by a representative of the American Club places the responsibility on that club for organizing the race next year, and already plans are being laid.

Interest in ballooning as a sport has received an impetus which has already carried it to the front, and now the practical side is appearing. It is interesting to note that sixteen balloons in this year's contest carried regular army officers either as pilots or assistants. The balloon holds an important place in warfare. Steps which are now being taken to develop ballooning in our own army show that we are taking the matter seriously, and that we are beginning to appreciate that we are behind other nations along this line. Practically all European armies have their balloon corps. Troops are regularly incorporated for this service, and by constant practice and experimenting they have brought the military balloon to such a point of perfection that its usefulness cannot be doubted. History has already demonstrated its value in the past. Thirty-six years ago the besieged city of Paris was able to defy the German besiegers and to maintain constant communication with the troops outside, thanks to balloons. More than seventy were sent out, carrying dozens of passengers, tons of mail and hundreds of carrier-pig-

eons, which were sent back into the city with valuable messages.

Let us not fail to appreciate the necessity for preparedness above the earth as well as on the earth, and when our next war comes, let us not be found wanting in this particular branch of military science.

V

EXPERIMENTAL FLIGHTS WITH A MAN-CARRYING AËROPLANE

By Israel Ludlow

FOR centuries man has tried to master the invisible pulsating atmosphere, which is intangible, yet capable of such gigantic strength; whose power rages in the storm, whispers in the woods, whirls the sails of the windmills, rolls the waves of the ocean into mighty billows, and bears the burden of a world-wide commerce.

By the application of natural and mechanical laws in certain directions, giant steam and subtle electricity propel at incredible speed the car and the boat. Man has outraced the beast on the land, and the fish in the sea. Only the initial steps have been taken in conquering the aërial domain, notwithstanding the fact, that winning the victory is not a question of the strength of material for construction purposes, or of making motors more powerful and active than the muscles which the bird exerts to fly. Reasoning from analogy, as well as from the premises of the problem, it is certain that the great highway of the air is soon to be traversed by man. There remains only the mechan-

ical problem of securing a form of aëroplane surface, which will give stable equilibrium.

Exact imitation of bird flight appears to be out of the question. A bird's wing with its quivering feathers, is governed by a number of delicate but strong muscles, much like the human hand, in that it cannot be exactly mechanically duplicated. The flight however, of some birds is like the flight of an aëroplane, because the pull of the beat of their wings is directly or almost directly in the line of motion. Mathematically it can be proved, using authorized tables of air pressure, that a plane equal to the area of the horizontal projection of the head, neck, body and outspread tail of these birds, if driven at a pace equal to that of their flight when flying at the greatest speed (the wild goose and the wild duck in their migratory travel, for example), would receive enough support as an aëroplane from the upward air reaction to equal their weight.

This is not true of birds of orthogonal flight, or of soaring birds, but in the instances where the weight, area of the body, and the speed of the bird in flight, combine to make an application of this theory possible, it is probable that in the case of these birds (whose bodies on their undersides are invariably flat, and whose bills are broad) that their wings act as propellers only; and the situation is analogous to an aëroplane drawn by screw propellers.

The gasolene engine has developed power stronger than the muscular strength of birds, and of less proportionate weight. An engine can be built weighing two or three pounds to the horse-power.

A wild goose exercises less than one twentieth of a horse-power to fly. Man, however, cannot hope to master the intuitive skill by which a bird preserves its balance, through flexing and reflexing its outstretched wings. He must, if he should wish to stay in the air with safety, invent a form of aëroplane surface, which has automatic stability and power of control.

The framework of the aëroplane I experimented with, was constructed of bamboo about 1¼ inches in diameter and the planes were made of light canvas, treated with paraffin, or sometimes with a preparation of pure gutta-percha dissolved in benzine. Fore and aft were two groups of superimposed planes; the middle planes being set at an angle with each other so as to form, with the upper plane, an inverted triangle. The illustration shows very clearly the shape of the aëroplane. The surfaces of the various planes were 5 feet in depth, with a total width of 25 feet. The construction was a series of cubes braced truss-like, by running steel wires from the corners of the cubes to the corners diagonally opposite. This method gave strength and rigidity of framework, together with lightness of weight that was astonishing.

It is well to follow up the principles of nature even though its forms cannot be exactly duplicated. It will be noted that the ends of a bird's wings range upward forming what is technically known as a dihedral angle insuring lateral stability. It is obvious that a dihedral angle insures this stability, inasmuch as in tipping sidewise the wing which is down has greater upward air

pressure than the wing which is inclined, with the resulting tendency of restoring the bird's equilibrium. The middle plane in each group of planes was a dihedral angle surface and the lowest plane was divided into two parts that the air might act more effectively. The open space between the forward and rear sets of planes decreases the effect of unequal air currents, as the sudden gusts are prevented from traveling the full length of the aëroplane. The bamboo rods crossing this space, act as a fulcrum against which undue air currents must pass.

Longitudinal equilibrium is gained through interposing this space between the fore and aft group of planes. It is apparent that any upward or downward tendency on one group of planes is counterbalanced by the opposite effect on the other planes. Experiment showed that stability increased with the widening of this space. The air blowing through the triangular opening formed by the dihedral angle surface with the upper surface, gives direction to the line of flight, prevents oscillation, and overcomes a tendency of the flying machine to turn around on the center of gravity. The position of the aviator is directly behind the fore group of planes; this when the aëroplane is in motion, was the point of the center of pressure, and the center of pressure altered very little with the varying angles of incidence and different speeds,—a very important point.

To fly the aëroplane a rope was tied to an automobile, and the other end was attached to the aëroplane. The automobile was driven at a speed fast enough to cause the aëroplane to rise in the air as a kite. The

first large aëroplane had the fault of being too heavy, and all efforts to make it leave the ground were unsuccessful. Until an automobile of 80 horse-power was obtained for towing purposes, no flights were successful, as the speed of twenty miles an hour was required at the start, which a smaller horse-power automobile was not capable of attaining when it had to contend with the drag of the aëroplane.

On the banks of the Hudson River, at the foot of West 79th Street was practically the only large unoccupied space in the borough of Manhattan that was suitable for the experiments that I wished to carry forward; the Park Department having refused the use of lands under their jurisdiction.

Within three blocks of this dock was a large square occupied by an old colonial house, famed for being one of the headquarters of Washington, during the Revolutionary War. In the rear of this house in the open air the aëroplanes were built. When they were finished they were carried to the dock for their trials.

Each aëroplane was placed at one end of this open dock, and about 200 feet of the best hemp rope ¾ inch in diameter was fastened to it. A length of about 50 feet was coiled and placed at the rear of the automobile, so that a good running start might be had before the pull of the rope acted on the aëroplane.

After numerous trials with ballast, Charles K. Hamilton, a professional balloonist essayed to ride in the aëroplane in one of its flights. The first attempts were unsuccessful, but improvement was gained with the construction of each succeeding aëroplane, and a suc-

cessful flight of the aëroplane carrying Mr. Hamilton finally became almost invariably assured.

At these trials the aëroplane was forced rapidly through the air at all sorts of angles of inclination; its equilibrium was violently disturbed by some of the causes that would affect a flying machine; the center of pressure on its surface was located; the form, the material and the extent of its surfaces were experimented with.

In the trial of the fifth aëroplane about two hundred and fifty feet of rope was used. Mr. McIntyre, the owner of the automobile, acted as chauffeur, and I sat in the rear seat with my hand on a slip knot, which would unfasten the rope in the event of an emergency. Mr. Hamilton took his place in a rope seat, just in the rear of the front planes, and the automobile was started at full speed. The slack of the rope was quickly taken up. The rope tightened, and the great white aëroplane, carrying its human freight, rose like a seagull one hundred and fifty feet in the air.

The dock was about eight hundred feet long, and the automobile at the end of it perforce came to a full stop.

This brought about a cessation of the uplifting force, as it shut off the source of the air current. Owing to the strains of previous experiments the plane surfaces did not balance each other, and instead of gliding gently down the aëroplane dived, striking when going at considerable velocity. It was completely wrecked, but Mr. Hamilton escaped unhurt.

Many other aëroplanes were constructed, each dif-

fering from the previous ones, and each showing to keen observation a difference in flight. In each of them Mr. Hamilton rode with his usual courage, giving evidence of absolutely no fear, and capturing the admiration of all beholders by his modest demeanor.

It was determined to make a flight high over the Hudson River, and a powerful and fast tugboat was obtained. The aëroplane was placed on the banks of the river, and the rope was attached to the tug. Mr. Hamilton mounted into his seat, and the tug started at full speed toward midstream, the aëroplane rose buoyantly upward on a strong gust of wind, the tug headed down the river. We intended to go to the Battery, eight miles away. More than six hundred feet of rope was let out and the aëroplane mounted nearly overhead.

From this point Mr. Hamilton could see the aspect of the country beyond the Palisades on the west bank of the Hudson, which was totally invisible both from the river and the high points of the New York side. Such an aid to observation as this would be invaluable to a navy ascending a river in a supposedly hostile country.

A mile and a half of the river had been traversed when, unluckily, a ferry-boat crossed the bows of the tug, causing it to stop. The aëroplane glided onward so fast that the tug was not able to take up the slack of the rope when it again started. The aëroplane settled gently on the surface of the water, and Mr. Hamilton was rescued by the attending launches.

The next trial was made in the South. Mr. Hamilton was engaged to fly the aëroplane in Florida in con-

nection with a series of automobile races run on the beach of the Atlantic Ocean. Those races were held under the auspices of the Jacksonville Automobile Club. I was invited to be present as a guest of the club, and accepted the invitation. After Mr. Hamilton had made a successful flight, and as a result of merry banter at the dinner-table, two members of the club and I agreed to make a flight together in an aëroplane capable of carrying our combined weight. The work was enthusiastically begun on the construction of a new and very large aëroplane. The services of a dozen men were secured, a noted physician, a retired army officer, and others rendered valuable assistance.

The beach at low tide was about six hundred feet in width, and very level, smooth, and firm. Two large automobiles were hitched together to tow. Without any hesitation whatever the two members of the Automobile Club came forward to take their places in the aëroplane with me.

I demurred, and insisted on trying it alone first. I took my seat and the aëroplane was tilted upward at its forward end, the signal was given to start, and under the impulse of the speeding automobiles the aëroplane rose as though it were flung into the air.

The rush of wind past the planes and through the braces was for a moment disconcerting, but I forgot it and looked down at the automobiles which appeared to be directly under me. I turned to look backward, and in comparing the level at which the aëroplane floated with the distant line of the Atlantic Ocean's horizon I saw they were very near the same. Then I heard an

ominous crack to my left, just in the rear of the forward set of planes. I saw that a wire brace had snapped and that a bamboo stick, released from the wired stay under the air pressure was bending in a curve. Very quickly, clear across the aëroplane one wire after another gave way and the forward planes bent upward. The aëroplane lost its lifting capability and began to fall with increasing velocity. I was something more than a hundred feet above when the accident happened.

The break occurred across the aëroplane along the line of the center of pressure, at which point the rope was attached, and above which I was seated. I had no sensation of falling.

In the few seconds of time, which elapsed between the first downward move and when the aëroplane struck the beach, I watched one wire after another snap, and the bending and breaking of bamboo. The rapid approach of the earth did not inspire any feeling of fear. I heard the confused shouting of the spectators, and then came the sensation of a tremendous blow. The point on which I was seated struck the beach first, and the rest of the aëroplane fell on me. I received a very severe injury to my back, and within half an hour was being rushed by train to New York for medical treatment.

The cause of the collapse of the aëroplane was due primarily to the fact that it was impossible to obtain suitable wire for bracing. Instead of steel wire, iron wire of assorted sizes was made to answer for construction purposes. Two secondary causes were, the

immense size of the aëroplane, upon which the air reacted with a force, I estimated at above fifteen hundred pounds, and the swift air current which in Florida blows with greatly accelerated speed. It was into this swift air current the aëroplane sailed. If it had been free, and not tied to the automobile by the rope, it would have risen higher without collapsing. The cause of the collapse was due to a defect which obviously can be remedied by putting stronger material at the point of weakness.

The result of my series of experiments was to discover a form of aëroplane remarkable for its automatic stability; a natural law of sizes became known; the efficacy of the surface from upward air pressure was determined; the trajectory of the aëroplane in flight was closely observed; and the value of the observations made is that they were not founded on any abstruse analytical reasoning, but upon practical experiments.

It is my opinion that when propellers and motor are placed upon this aëroplane, it will be a perfect dirigible flying machine.

VI

HOW TO FLY AS A BIRD

By John P. Holland

THOSE who desire to travel like the birds through nature's great highway, the atmosphere, must not be discouraged by the wise ones who advise them to attempt to do only what is practicable, telling them that the problem of flight is in the same category as perpetual motion, the search for the philosopher's stone and for the fabled fountain of perpetual youth.

Practically the same thing was said regarding a proposition I made over thirty years ago to our government to build an experimental submarine boat. The late Commodore Simpson reporting on that suggestion to the Navy Department said it would be of no use, because no one could be found to operate it, and because it could not be directed under water. The attempt to do so, he added, would be practically an aggravated case of a man trying to find his way in a fog.

A few years before his victory over the Spanish fleet at Santiago, the late Admiral Sampson, in a spirit of courteous kindness, advised me to discontinue my efforts to persuade our Navy Department to experiment with submarine boats as my time would surely be

wasted. He assured me that even though such a boat could do everything that I had proved to be practicable with my second submarine boat in 1881, yet he could see no use for them in the navy.

Still another high authority, Herr Busley, the head of a German Imperial School for some division of that naval service, asserted that no man of experience in marine design or construction, no naval architect, had ever been foolish enough to waste his time on the construction of submarine boats, and that only unsuccessful medical doctors, school-teachers and other outsiders, ever made attempts in that direction.

He fairly hit the mark in that observation as I happen to be an ex-school-teacher. Even with this criticism of submarines they are now included in the building program of all important maritime countries, and they already have had influence in the designs of their new ships. They are no longer laughed at or ridiculed. And what is still more remarkable, I am credibly informed that Herr Busley himself now favors the "only real thing" in submarines, a German invention.

This remarkable change in the views of naval departments, of boards of admiralty and other officials connected with the management of naval affairs, in this country and in Europe, was not due to any striking improvement in principle, or gain in efficiency of this type of boat, between the date of the successful experiments made with my second boat in 1881 and the exhibition of the *Holland* to Admiral Dewey, on the Potomac, in April, 1901, but simply and solely to the un-

biased opinion that eminent sea-captain frankly expressed, which carried universal conviction and was absolutely beyond question.

Although it has been remarked that professional persons are generally conservative, that is, opposed to the acceptance of new ideas, and that many of them even manifest a tendency to run in a rut and to keep running there persistently, yet, in this particular, they are no different from the rest of humanity.

Since the very beginning of things the simplest and most rapid mode of animal locomotion has been daily exhibited before their faces, as if to provoke them to imitate it, yet nothing worthy of notice has ever been done toward its accomplishment. It is true that men have always desired to be able to fly like the birds, and in cases of dire necessity, as in cities reduced to extremity by beleaguering armies, or travelers dying of hunger or thirst in the desert, that power was even more ardently but fruitlessly desired.

From very ancient times men vainly attempted to fly with crude imitations of wings operated by their arms. Those who happened to survive their experiments might be pardoned for believing that the power of levitation was mysterious because it proved to be beyond their reach, but the general tendency of humanity, even at the present day, to attribute obscure natural phenomena to some occult power, or to accept the decision of some "authorities" that it is mysterious, saves them the trouble of investigation, and they are satisfied. Witness the belief in the work of Pluto and of Jove in the thunder and lightning, among the ancient Greeks,

and of the Thunder bird among the modern Zulus and Hottentots.

But the most astonishing exhibition of that kind is to hear educated men, investigators of natural phenomena, at the present day, talk about the mysteries of flight and soaring, or attributing superhuman intelligence to birds in the art of balancing, selecting favoring currents, etc., instead of openly confessing that there must be some simple functions of the natural apparatus for flight that they have mistaken or misunderstood, or which until now, they have failed to notice.

Why do they propose explanations of bird flight that cannot possibly account for even one half of the support required in certain plain cases, and yet not inform us regarding what is lacking thereto? Even though they would not wish to be credited with belief in the occult, equaling that of the ancient Greeks, or the modern Zulus, yet they afford us no alternative explanation.

It is unfortunate that the net result of the investigations of those who have studied bird flight is that it is far beyond human reach if they are not greatly mistaken.

Almost without exception they maintain absurd theories that cannot in the nature of things be true, that are refuted before their faces every day by every flying thing, and that are far from being reasonable and simple, as are the natural functions regarding which they dogmatize.

We have been assured by conscientious and zealous workers in this field that air reaction due to down-beat-

ing wings must be competent to balance the bird's weight.

This takes account only of the support afforded while a bird is making its down stroke. The source of support during the elevation of the wings, they generally credit to the mystery account, although Mr. O. Chanute, who is probably the most painstaking and industrious of them all, asserts that aëroplane action must be credited with giving great assistance.

The utter inadequacy of air reaction from downbeating as a means of support during steady flight must also be credited to the mystery account.

Still another mystery is thus formulated by Mr. O. Chanute in his valuable and interesting work, "Progress in Flying Machines," page 251. "There is good reason to believe that the output of energy appertaining to the motor muscles of birds in proportion to their weight, which, as we have seen there is good reason to believe, develop work in ordinary flight at the rate of one horse-power to twenty pounds of weight, and can, for a brief period, in rising, give out energy at such a rate as to represent an engine of only five or six pounds' weight developing one horse-power." That is, a twenty-pound bird develops one horse-power during steady flight, and a five-pound bird develops one horse-power when rising, say from the level, and also when alighting.

Maintaining this proportion, a man who is ambitious to fly by his own muscular energy must be able to develop 150 divided by 20, equals 7½ horse-power continuously during steady flight, and 150 divided by

5, equals 30 horse-power when rising from the level and alighting.

We need not delay longer over the mystery account, as it is quite a long one, as will be apparent later.

With this encouragement in mind, we should act wisely in quitting the study of flying for good, in case we find that the authorities are not in error, or else follow it up to an actual demonstration if we find that by a common-sense application of the laws of physics, and by comparisons with the perfect examples afforded by nature, that they are mistaken.

For this purpose we may study a proposed design for a machine to be operated by muscular energy alone. We shall then encounter the ordinary "mysteries" of the case and see how nature treats them, as well as determine whether a man can operate it himself even though he possesses less than one one-hundred-and-twentieth part of the muscular power that the authorities assure us is quite essential.

What we shall most assuredly discover from our study is the extreme denseness of human stupidity in failing through all past ages to understand the simplest and most rapid mode of animal locomotion, although man was ingenious enough to cloak over his laziness of mind and neglect, and rest satisfied by assuring himself that the whole subject was an impenetrable mystery.

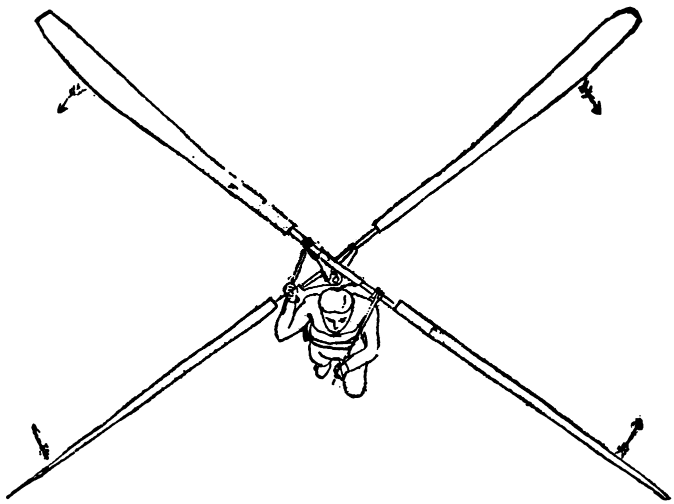
No one needs to excuse himself, because we are all together in the same boat and in very good company. Some very distinguished scientific gentlemen and great inventors, among whom may be named Thomas A. Edison, Professor Bell, the late Pro-

fessor Langley, O. Chanute and many others in this country, as well as very many equally distinguished scientists in Europe, have devoted much study, although vainly, to this interesting subject.

My first design was made in 1863, shortly before I began the study of submarines, but I had no suspicion of the influence of the chief, almost the only, natural force employed by every flying animal, until it occurred to me, not as the result of study or industry but purely by accident a few years ago. Therefore, this discovery is not an invention, and I have great pleasure in thus describing it publicly in order that some one may be stimulated to lead the way into what will be practically, a new order of existence.

INDIVIDUAL FLYING MACHINE DESIGNED TO BE OPERATED SOLELY BY MUSCULAR ENERGY

It may consist of two transverse wing arms at the operator's back, one of them at the level of his neck, the other one being set about four or five inches below his hips. These wing arms are fastened on short tubular shafts provided with ball bearings at each end of each shaft. These shafts are carried by bearings on a foundation plate, or substitute for the bird's backbone, which is provided with rigid metal carriers at its sides, near the middle of its length, that extend around the operator's sides for the purpose of holding the treadle guides, and a frame carrying a diaphragm on which his body rests in a nearly horizontal position, face downward, when he is in full flight.

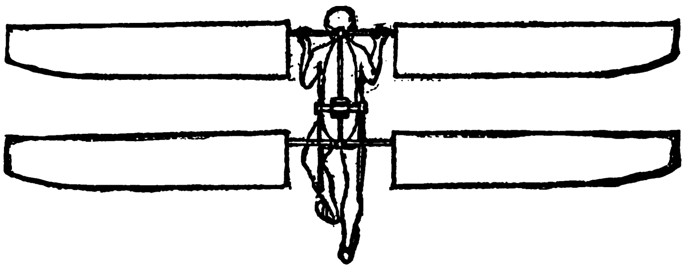


Carried on bearings fastened on the foundation plate are also placed two short, transverse tubular shafts opposite to each other, their approaching ends carrying miter gears, which gear into two corresponding gears placed on the inner ends of the tubular shafts that have their outer ends fastened to the transverse wing arms. The short transverse shafts carry near their outer ends a grooved metal arc, carrying a small wire rope, which extends backward, or downward, from where one end of each is fastened to each arc radius to a treadle at either side, at the lower end of the apparatus.

It is evident that when the short shafts are connected by miter wheels, and the treadles are pushed alternately, the operator's body being inclined forward, or nearly horizontal, that the two wing arms will vibrate in opposite directions.

The wing sails are set on pieces of wood bent to the

proper curvature and attached to metal rings through which the wing arms pass. Pins passing through the arms limit the swing of the cross pieces around them



to about forty-five degrees in order to provide that the sails may automatically feather, that is, change their inclination when the machine is starting in a calm and before it has attained sufficient velocity to render feathering unnecessary.

Provision is made in the wing arm bearings to permit of the arms being revolved simultaneously around their axis with the object of controlling the inclination of the sails. This is accomplished by means of two light handles depending one on either side, from the forward wing arm and by a connection between both arms.

By means of handles referred to, the machine can be operated by the hands, or it may be driven by the feet by means of the treadles, or both means of operation may be employed together when the hard work of starting or alighting in a calm, from the level, happens to be necessary.

The inertia of all the moving parts is cushioned by

a device attached to the radial arms of the arcs carrying the wire rope on each side. The effect of cushioning is to reverse the direction of motion of the wings without shock, and thus economize power and facilitate speed.

It is evident that each half of each wing arm, with its sail balances the other half with its sail, and that compensation to obtain balance is therefore unnecessary.

The wing arms in the machine illustrated on page 64, are made of No. 22, one and one-quarter inch steel tubes in the middle, tapering to three-eighths inch diameter at the ends. These tubes will be strong enough to dispense with trussing which is inadmissible.

The weight of the machine illustrated will be, when it is completed, thirty-five pounds, but with more suitable material and better workmanship that weight can be reduced to fifteen pounds. This figure should be taken as the weight of an effective machine, although it may weigh more.

It is evident that the mysteries of stability and balancing will be eliminated in this machine, because the center of gravity of apparatus and operator together will be about fifteen inches under the center of support, which is unchangeable and effective at the crossing of two diagonal lines joining the center of effort of the wings that are situated diagonally.

The center of resistance will be on the same plane as the center of thrust, or propulsion, and there can, therefore, exist no tendency to tip upward or downward.

The anterior edges of the wings being thick and convexed, eliminates the risk to the operator of meeting the fate of Lilienthal. With the fore and aft section of his planes or wings nearly corresponding with the plane of his direction of motion, and his apparatus moving at comparatively slow speed, there is little wonder that, owing to a slight movement of the operator, or to a vertical current of low speed, their upper forward surfaces took the wind, or in nautical phraseology were taken aback.

This apparatus is designed to imitate as closely as possible the mechanism existing in nature for the attainment of flight through the air, because the unnumbered failures of attempts that aimed at employing only crude substitutes for natural means and methods, prove that its plans are the best, and that the degree of success of devices for these purposes will depend on the exactness with which its perfect examples are followed.

It will be shown herein that the mechanism of natural flight has never heretofore been properly understood. Until within the last decade it was generally believed that the necessary aërial support of flying animals was afforded solely by the reaction of air against the descending wings, and that during its flight a bird produces a reaction at the center of effort of each wing competent to support at least one half of the bird's weight.

A bird's wing during beating, or rowing flight, is a lever of the third order, having the fulcrum at one end, the weight or working-point toward the other end, and

the power applied at some point between them. The inner joint, at which the wing is attached to the body, is the fulcrum. The power is applied at the point of attachment of the pectoral muscles to the wing arm.

The working-point at which the power is utilized being taken as the center of effort of each wing, the distance from the fulcrum to the center of effort is from four to nine times greater than the distance from the fulcrum to the point of attachment of the pectoral muscles, depending on the species of bird. This ratio generally increases with the size of the species, being greatest with soarers, and about nine in the case of the great wandering albatross, the information regarding which is sufficiently definite for purposes of comparison.

If the reaction equal-to-weight theory is correct then the pectoral muscles must contract at each wing stroke with a force equal to nine times the bird's weight, in order that reaction equal to the weight may exist at the centers of effort, leaving the question of support, during the intermission while the wings are rising, entirely out of consideration, or rather crediting it to the mystery account.

The same bird makes wing beats at the rate of 110 per minute, through about 90 degrees of arc, when rising from the water. Therefore, if the pressure at the centers of effort must be equal to the weight, 20 lbs., it must be exerted at the rate of 110 beats per minute, the vertical speed of the centers of effort being 21.5985 feet per second; 20 × 21.5985, divided by 550, equals 0.7854 horse-power.

The force actually required for support by air reaction alone during one down-beat is equal to the bird's weight divided by the ratio of the levers in the wings 9; 20 divided by 9 equals 2 2-9 lbs. at the centers of effort. Reaction 2 2-9 × 21.59, divided by 550, equals 0.0872 horse-power, equals 43.96 foot lbs. per second, and this force is exerted only when the bird begins to rise from smooth water or when alighting.

The source of support during the elevation of the wings will be pointed out later.

Another reference to nature will reveal the source of the supporting power during flight. An albatross flying in calm weather, beating its wings and not soaring, supports its 20-lb. weight with very little apparent effort. The wing spread is 10.5 feet, the radius of the center of effort of each wing is about 3.75 feet, total wing surface 5.5 square feet, and the vertical speed of the center of effort of each wing is at the leisurely rate of 5.5 feet per second. The wing reaction to direct down-beating is, in this case, 0.0703 lbs. per square foot, and the total direct reaction is 5.5 × 0.0703, equals 0.386 lbs.

Thus it falls short of adequate support, and it is in action only while the wings are descending. Nor can aëroplane action of the wings, as it is at present believed to be employed in steady flight, afford any satisfactory explanation of the bird's means of support.

Suppose that, as is commonly believed, the wings do work as aëroplanes during their elevation. The speed in this kind of flight is from 30 to 35 miles per hour. The pressure on a flat surface of a wind blowing 35

miles per hour is 6.125 lbs. per square foot. The inclination of the wings when acting as aëroplanes during flight is generally calculated to be about 6 degrees. The normal pressure of the wing surface due to this inclination is 0.207 of the pressure at no inclination, the vertical, or lifting component is 0.206, and the horizontal component is 0.0217 of the same. The lifting force due to aëroplane action under these conditions should therefore be $5.5 \times 6.125 \times 0.206$, equals 6.939 lbs.

Mr. O. Chanute believes that 30 per cent. should be added to this amount because of the greater efficiency of concaved surfaces than of the flat plane surfaces: 6.939×1.3, equals 9.02 lbs.

These results are surprising in view of the consensus of opinion of the authorities cited by Mr. Chanute. Instead of the 7.5 horse-power that the albatross should develop in order to be in agreement with their theories, we find only 0.386×5.5 feet per second, divided by 550, equals 0.00396 horse-power, equals 2.178 foot lbs. per second, developed as the result of direct reaction in steady flight.

Because the wings act, in this case, as a vibrating propeller, 60 per cent. of this power is expended as propulsive force and there remains as direct lift, during down-beating, only 0.1544 lbs., and no help whatever from this source while the wings are rising.

On the supposition that aëroplane action is effective during the elevation of the wings, we find that the resulting lift can be no more than 9.02 lbs., less than one

half of the bird's weight, and this help cannot exist during the descent of the wings.

It is evident, therefore, that if the bird's support is to depend on direct reaction during the down-beating, and to aëroplane action during wing elevation, there must be sixty times more elevating power developed during the rise of the wings than during their descent. But the maximum lifting-power exerted, during one half the time is less than one half of what is required and of what most certainly exists.

This is all that existing theories suggest or permit in explanation of the conundrum of how the twenty-pound albatross supports its weight during beating or rowing flight, but it is very much less than one half of what is wanted and of what is actually provided and employed in nature, even though the source of the remainder has thus far escaped observation.

It is certain that there can be nothing occult in the performance of the albatross described above, and it is probable that the failure, thus far, to explain it, and to solve the mystery of soaring, is owing mainly to the influence of incorrect theories and to omissions and oversights in observing the results of experiments and the natural function referred to above. Yet the bird moves through the air like a thing without weight, and not merely as a floating object that rests on something else. It is remarkable also that it moves in circles, curves and reverse curves, and that it descends to the surface of the water and rises again as if there were no such thing as gravitation to hinder it. As soon as it acquires a certain horizontal speed it is immediately

endowed with the hitherto incomprehensible power of levitation. Its weight is certainly supported, and supported constantly, no matter whether the wings are beating downward, rising, or extended in soaring.

The bird's support cannot be due to aëroplane action, that is, compression of air under the advancing wings which, it is calculated, must carry their anterior edges about six degrees higher than the posterior edges in order to produce sufficient effect as aëroplanes. We have seen that with six degrees inclination the support afforded is less than one half of what is required even during one half the time it is flying. But we also have incontestible evidence that the albatross soars horizontally with the under surfaces of the wings held quite flat in the fore and aft direction. We have equally good evidence that the turkey buzzard generally soars horizontally with its wings similarly held flat. In neither of these cases can what is commonly known as aëroplane action exist.

Neither can the concaving of the under wing surfaces afford any help, although so much has been attributed to its efficiency. It will be apparent to any person who examines the wing of an albatross preserved in any museum of natural history, that the surface under the primary feathers is quite flat, and that if a flat card or board is held, fore and aft, under the secondary and tertiary wing feathers, that a pressure representing what actually exists there during flight, *viz.*, one-fortieth of one pound per square inch of surface supported, that that part will lie perfectly flat, thus establishing the correctness of the observations quoted

above and compelling us to reject all explanations of bird flight thus far proposed.

Very costly and careful experiments were made with inclined planes by the late Professor Langley, Sir Hiram S. Maxim, Mr. O. Chanute, and others, in this field, as it appeared to be the most promising of affording light on the mysteries of flight and soaring. They determined the varying degrees of reaction from pressure of air on surfaces of various sizes and of varying degrees of inclination, and they found how many pounds' weight could be lifted per square foot of inclined plane, and per horse-power applied to moving it horizontally. But the vitally important matter, the agent that every flying thing employs to sustain its weight, *defective, or minus pressure or air rarefaction over the wings and tail,* remained almost entirely unnoticed, and certainly never defined as the important factor in producing levitation.

A study of the transverse, vertical section of a bird's wing when it is extended in flight will render it clear that defective pressure must exist, during flight, over the greater part of its upper surface when a certain speed is attained. The wing, in this case, moves approximately edgewise through the air at good speed, and the air may either impinge on the under surface or move parallel with it. The air stream is divided by the wing's anterior edge, the body of the stream represented by the wing's thickness at each transverse section being deflected upward and over the upper surface by the wing's curved forward section, the extreme forward edge of which is nearly on the same plane as the

under surface of the wing. The air thrown upward by the wing's curved edge cannot recurve instantly and get into close contact with the upper surface on account of its inertia. The air pressure, therefore, drops below atmosphere between the passing current of air and the wing's upper surface, the space between them being probably filled by eddying currents at a pressure below that existing in the free air depending on the relative speeds of the air current and the wing, and on the degree of their inclination to each other.

How very small may be the proportion, or degree, of defective pressure over the wings required for support in the case of the flying albatross considered above may be easily ascertained.

The total wing surface is 5.5 square feet—792 square inches, to which add 8 square inches for the tail, total 800 square inches.

It was shown above that the vertical component of the direct reaction due to the down-beat of the wings was only 0.1544 lbs., and this is so small, considering the bird's weight, that it may be neglected.

The bird's twenty-pounds' weight will therefore be supposed to be entirely supported by the defective pressure over the wings.

Bird's weight, 20 lbs., divided by supporting surface, 800 square inches; equals 1-40 lb.

The effect of negative, or defective pressure on one side of a plane exposed to the wind being equivalent to just as much positive pressure on its other or exposed side, the one-fortieth pound defective, or negative pressure per square inch on the wing's upper surface is

equivalent to one-fortieth pound positive pressure on each square inch of their under surface.

The surface being 800 square inches, $800 \times 1\text{-}40$ equals 20 pounds, the bird's weight.

This helps to explain the increasing lifting efficiency of inclined planes with increasing inclination.

The solution of the problem of flight was near, when, in 1880, it was proved that a ship's propeller, in most cases, moved the ship as much by pumping water from ahead as by pushing it directly backward.

It was still nearer when Hargraves invented the box-kite, but his apparently satisfactory explanation of reasons for its efficiency prevented a search for the true one.

Any person can readily satisfy himself of the usefulness of defective pressure by taking an ordinary box-kite, measuring its lifting power and weight against an ordinary kite having the same lifting surface, then continuing the sides of the box-kite vertically over the upper lifting planes until they project above them a few inches in front, at the edges of the sides, and have the upper edges of the lengthened sides made horizontal when the kite is flying.

The gain over the original box-kite will be clearly apparent.

The lower plane in the box-kite fully exploys defective pressure because the vertical side planes joined to its edges prevent the outer air from flowing inward over the upper surface of the lower plane to destroy the defective pressure existing there and thus mar its efficiency. Now, if a rectangular portion of each of the

side vertical planes and of nearly the full fore and aft length of the lower plane be removed from their lower ends so as to permit the outer air to be drawn in by the rarefaction existing over the lower planes, and if the side projections over the vertical planes be removed, it will be found that the efficiency of the box-kite will be destroyed, and that it will require a much stronger wind to cause it to rise while it is in this condition, although its steadiness will not be noticeably impaired.

If convexed planes be substituted for the flat planes in the kite the mystery of bird levitation will be quickly solved to the experimenter's satisfaction.

There are good reasons for believing that the still deeper mystery of soaring flight is capable of an equally simple explanation. In the case cited above, of an albatross flying in calm weather, it was shown that the propelling, or drift force was only 0.2316 lbs.; that is, about one eighty-sixth part of the bird's weight applied as propelling force suffices to overcome the frictional resistance of the air, which must be very little indeed against the exceedingly smooth surface of the bird's body and wings, and it maintains speed enough to preserve a suitable degree of defective pressure over the wings and tail to afford necessary support.

A study of Mr. O. Chanute's table of lift and drift force for aëroplanes propelled through air while inclined to the horizon indicates that the inclination of the albatross's wings should be about forty-five minutes of arc if they were flat planes. But as they are thick edged, convex surfaces, their action may differ considerably from the performance of flat planes.

The chief difference is that the angle of inclination may vary a good deal from zero, or even minus, to a considerable positive angle without notably affecting the degree of minus pressure above them. To employ nautical phraseology, the bird may sail even into the wind's eye and still have support and steerage way.

It is also very doubtful whether the inner halves of the wings that are chiefly effective as supports have, during flight, any inclination to the air streams they encounter. If they have no inclination, air resistance must be reduced to a minimum, and the proportion of power expended in propulsion, already shown to be very small indeed, must be still further reduced.

Propulsion is done by the outer halves, or rather, about two fifths of the wings, which are much less rigid than the inner parts that are held stiff enough to support the weight steadily while flying.

The outer parts indeed do their proportion of supporting, but being more flexible, they yield to the extra pressure during the down-beat.

The posterior edge is forced upward and the wing thus forms half of a vibrating screw propeller that wastes no power in indirect action, such as happens with the best propeller designed by man.

Referring again to the case of the albatross employing beating flight in calm weather; the speed of the centers of effort of its wings was 5.5 feet per second, and the radius of the centers of effort was 3.75 feet. When the wing stroke was made through 90,° the down-beat occupied more than one second, and when the stroke was through 120° nearly 1.5 seconds were

required to complete it, and just as much more time to raise them. This is leisurely work indeed. It is plainly perceptible that during steady flight no variation of the supporting power is visible, although if it varied much the bird should certainly drop by gravity through a considerable distance during the one and a half seconds required to elevate the wings if support depended on the reaction due to the previous stroke. Again, because their under surfaces are held flat in the fore and aft direction, there can be no air compression under the wings and therefore no support from that source. It has been shown above that considerable air rarefaction must exist over the wings while the bird is moving at good speed, and it has also been shown that the degree of rarefaction required for complete support is that required to produce a compensating pressure under the wings of only one fortieth pound per square inch, equal to only sixty-nine one-hundredths of one inch water pressure.

This evidence clearly leads to the conviction that the chief and almost the only source of support during steady flight is air rarefaction over the bird's wings and tail.

This support is constant during flight whether the wings are rising, descending, or extended in soaring.

There is very little less lift from rarefaction of air when the wings are rising than while they are descending, because the bird's horizontal speed is about nine times greater than the vertical speed of the centers of effort.

It has been observed that in windy weather the bird seldom beats its wings, but swings in curves and cir-

cles, the plane of the wings, or rather the transverse axis through the body and wing tips, constantly changing its inclination to the horizon in every direction, chiefly sidewise. It is evident that the descending wing can always exert propelling force when the tail and rising wing are employed to throw the bird's momentum on the descending wing.

Some observers notice that in a wind requiring close reefed topsails, that is, in a gale, the albatross does not soar continuously, but makes an occasional wing beat, evidently to maintain the speed necessary to hold the minus pressure or rarefaction that affords support.

A captured albatross liberated in mid-ocean from the stern of a steamer extended its wings in its descent and, not touching the water, soared away without making a single wing beat while it remained visible. The available energy for this performance was obtained from the bird's weight of say 20 lbs., falling possibly 30 feet, 20 × 30 equals 600 foot lbs.

It may be noted that the angle of inclination of the wings during beating flight must not be considered in reference to the horizon, but to the resultant direction of air streams intercepted at any point in the wing in connection with the wing's motion.

All soaring birds are admirably fitted for the development and maintenance of minus pressure over their wings. They have to do little else during flight than to keep the air pumped out that happens to leak upward through their wings, or endwise from their inner ends, into the places where defective pressure must be maintained.

The work of propulsion is, on account of their prac-

tically perfect shape and surface, reduced to the work of overcoming air friction against their bodies and wings, and that is almost below calculation.

Humboldt, Darwin, and other naturalists noticed that the large vultures generally began their flight by launching themselves from an elevated position, extending their wings during a short descent evidently made to acquire the velocity necessary to establish defective pressure, and then soar in circles, curves and reverse curves until they disappeared beyond some neighboring elevation, or by gradually rising until they passed beyond the range of vision.

The reverse method was adopted when alighting. The bird approached its resting-place at a lower level. When it came near enough it turned upward and arose until its energy of motion was nearly absorbed. If any remained when alighting it was checked by a few vigorous wing beats against the direction of motion.

An interesting observation of sparrows trying to rise vertically in a fence corner when there is no wind, will help support the views set forth above regarding the forces utilized in bird flight.

The bird's body was vertical in each case and the wings vibrated almost horizontally, but at much higher speed than in ordinary flight.

It was very plain in the shape of the blurred stroke made by the rapidly moving wings that the tips of the primary feathers reached nearly two inches higher at the ends of the strokes than they did at half-way when moving forward and backward.

Fanning the air they were for certain, and fanning

it hard, with the fronts and backs of the wings alternately, having positive pressure on one side and defective pressure or rarefaction on the other, and the secondary feathers appeared to be doing most of the work.

The higher speed of beating, when rising vertically, is rendered possible by the shortening of the radii of inertia due to moving the ends of the primaries forward. By raising the wings in this way nearly double power is exerted in equal time, because there is no intermission and on account of the increased speed of beating.

It is interesting to notice that the sparrow when thus rising vertically moves upward very slowly, certainly not faster than one foot per second, and it is very clear that he is exerting his utmost strength. Yet he often gives up the attempt, especially if the fence happens to be much over five feet in height, and he takes risks by attempting to escape in some other direction rather than face the work that he knows is beyond his strength.

Now if a vertical rise of say eight feet is beyond the sparrow's strength when he is producing an air reaction on one side of his wings, which, plus the rarefaction on their other sides is only a trifle more than can lift his weight, how very much less must be his work when he is flying horizontally?

Very clearly the lift due to compression of air under his wings can never come anywhere near equaling his weight. It does not do so when he is making a supreme effort to get over a fence, and in his horizontal

flight it can amount to only a small fraction of the equivalent of his weight.

OPERATION OF FLYING MACHINE

It will be perceived that in the machine illustrated there can be no intermission in the development of direct reaction, even though that is a matter of little importance, excepting at the times of starting and stopping, when, owing to the want of horizontal speed, the intensity of air rarefaction over the wings is much reduced.

DETERMINING THE PARTICULARS OF THE MACHINE

Suppose the machine weighs...............	15 lbs.
and that the operator weighs...............	140 "
	155 "

If we take the albatross as our model, the great wing spread of the corresponding machine, more than twenty feet, would render it too unwieldy to be conveniently handled by an individual.

As we are free to take any other soarer than the albatross for a model, suppose we take the thirty-pound California vulture of eight feet ten inches wing spread.

The cube root of 155 divided by 30 equals about 1.72 and this is the dimension ratio.

8.83 × 1.72 equals 15.1876, say 15 feet 2 inches wing spread.

Proportionate speed for our machine would be as the square root of the dimension ratio, 1.72 equals 1.31.

Suppose the speed of the vulture is 30 miles. 30 × 1.3

equals 39 miles per hour. But because the friction of our machine will be much greater in proportion than the vulture's, we must be content with much lower speed, say 30 miles per hour.

Its wing surface will be in the proportion of the square of the dimension ratio, 1.72. Dimension ratio 1.72 squared equals 2.9584×7 square feet surface of the vulture's wings equals 20.7088 square feet for the wing sail area.

The spread of our wings being 15 feet 2 inches, we shall make them 1.25 feet wide, narrower in proportion than the vulture's, which will give about 18 square feet surface per pair and 36 square feet surface in two sets of wings.

The radius of the center of effort of each wing will be 5.687 feet.

The weight divided by the radius of the center of effort, 155 divided by 5.687 feet equals 27.25 lbs. at the two centers of effort of the two descending wings, and say 13.6 lbs. at the center effort of each wing.

TO ASCERTAIN THE SPEED OF WING BEAT NECESSARY TO BALANCE THE TOTAL WEIGHT

WEIGHT 155, divided by radius of center of effort, 5.687, equals 27.25 lbs. pressure to be exerted at both centers of effort together, and 13.6 lbs. on each sail.

The area of each sail is 9 square feet.

13.6 divided by 9 equals 1.51 lbs. per square foot. Square root of 1.51×200 equals wind speed to give this pressure, equals 17.38 miles per hour, equals nearly

25.5 feet per second. This 25.5 feet per second is the speed of the center of effort during the initial strokes when the machine is starting.

The length of the circular arc described by each center of effort during the first down-beats is 11.9 feet. 11.9 divided by 25.5 equals 0.46 second per down-beat. That is, the first down-beat should be made in a trifle less than one half a second.

This is the same as the work that a man would perform in running up a short stairway at the rate of 4.48 feet per second and carrying a weight of 15 lbs. on his back. This is nearly equal to running up eight steps per second, taking two steps at a time. But this hard work would continue for only a very few seconds because air rarefaction over the wings due to speed of translation begins immediately and increases very rapidly until only propelling force is required, the weight of the machine and operator being taken by the positive pressure due to air rarefaction, as in the case of the albatross cited above.

This also represents the work to be done in starting from the level, the most difficult condition. Should the start be made from an elevation so that a descent for the purpose of acquiring speed would be possible, the initial work would be greatly reduced.

Starting in a 20-mile head wind would take 72 lbs. off the total weight to begin with. In a very few seconds the speed would increase to 29.3 miles, when rarefaction would support the total weight.

It was shown above that in the case of the albatross traveling 35 miles per hour, equals 51.33 feet per sec-

ond, that the total energy exerted by the bird in order to support its weight and to maintain its speed was represented by a total air reaction of 0.386 foot lbs. per second.

It is reasonable to assume that the vulture, being as clever a soarer as the albatross, will require, to develop energy at the same rate, power only in proportion to its weight, its weight being 50 per cent. greater than that of the albatross by that proportion.

0.386 × 1.5 equals 0.552 feet lbs. per second. This represents the work of the vulture during ordinary flight.

Our machine being 1.72 times larger lineally, will require 1.72 cubed times more power for steady flight. 1.72 cubed equals 5.166.

But even though we may be able to construct the wings of our machine so that they may be almost as frictionless as those of the vulture, yet it does not appear to be possible to provide that both the operator and the body of the machine can be so arranged and covered by smooth surfaces that their friction can be reduced to anything near what would compare with that of the bird, bearing in mind that if they were equally frictionless the proportion would be as the square of the lineal dimensions, that is, 2.9 times, say three times greater.

It will be reasonable and safe therefore to provide that the operator must develop say 10 times more work per second than the preceding calculations call for. 2.85 feet lbs. per second multiplied by 10, equals 28.5 feet lbs. per second.

Let us compare this with the ordinary work of a laborer working 10 hours per day. He exerts continuously, while working, one eighth to one tenth horse-power. One eighth horse-power equals 550 divided by 8 equals 68.7 foot pounds per second, and one tenth horse-power equals 55 foot lbs. per second.

But our machine should require only 28.5 foot lbs. per second, that is, about one half the work of a laborer.

A man walking at a moderate rate of speed, say 3 miles per hour, does work equal to lifting his weight through one twentieth of the distance he travels in any given time. At 3 miles per hour he travels 4.5 feet per second.

4.5 divided by 20 equals 0.225 feet per second. 0.225×155 lbs. equals 34.875 foot lbs. per second.

But the work of propelling our machine through the air at a speed of 30 miles per hour cannot exceed 28.5 foot lbs. per second, which is much less than the work a 155 lb. man does in walking 3 miles per hour.

It appears to be clear that both the weight of our machine as well as its speed may be greatly increased before we reach the limit of work done for ten hours daily by an ordinary day laborer.

Of the two kinds of apparatus which thus far have been proposed for mechanical flight, *viz.*, individual flying machines operated by muscular energy, and aëroplane machines operated by some kind of engine, or motor, the individual flying machine has been considered worthy of consideration before the other kind, because, even though it will be much inferior to en-

gine-driven aëroplane machines in speed, radius and carrying power, yet it will be incomparably more important because neither machinery nor fuel will be required, thus eliminating the risks of disabled engines and failure of fuel supply. It will also be safe and simple in construction and operation, smaller and lighter, always available because it will require no supplies and always ready for instant use.

After the first necessarily crude and imperfect machine has demonstrated its practicability, we may look for their rapid development in simplicity and efficiency, as well as reduction of cost that will place them at everybody's service. It is evident that a machine constructed of Krupp steel in suitable forms can be built of equal strength and of much less than one half of the weight of an effective machine of the materials now available.

For example, the thirty-six-pound machine referred to above employs heavy cast iron gears, steel parts that in places are much too heavy, and aluminium in unsuitable sizes in many cases.

As practicable machines of both kinds would be invaluable in warfare, it is only simple justice to humanity to prevent any military power from "cornering" or monopolizing their use by thus placing it in every one's power to construct and develop them unhindered.

Having practically emptied the bag of mysteries that for ages have hindered the development of winged flying machines we shall now consider the much simpler problem of engine operated aëroplanes.

This is a simple matter in comparison with winged flight, because there are practically no mysteries to be encountered, nothing in fact in the shape of a serious difficulty, not even excepting the "serious problems of stability and balancing," of which we are warned by some investigators, especially in the case of our machine encountering vertical air currents.

Regarding the difficulties of stability and balancing, there is no difference in these things between aërial machines and submarine boats. Both cases are exactly similar in the essential requirements that the center of gravity must be maintained unchangeably in one position and that it must be held unalterably under the center of support, or buoyancy.

The center of resistance must also be approximately opposite the point at which the propulsive power is applied, although when rudders are employed, this matter is not of much importance. But it is essential that the relative positions of these centers have no tendency to change unexpectedly.

Regarding the dangers of vertical currents. They exist in water as well as in air, yet in the hundreds of dives I made in my first four submarine boats in the Passaic River, and at many points in New York harbor between Hoboken and Sandy Hook, in all kinds of weather and in all stages of the tides, I never noticed any disturbance of movement, or other perceptible effect, from them. In fact while closed up in the moving boat there was no evidence of their existence.

The reason is clear. The horizontal speed of the moving boat is so much greater than the vertical speed

of the current that the latter makes no impression on the trim, or on the direction of motion.

Why should there be any difference in the case of machines floating and moving in air?

This objection cannot be dignified by calling it a mystery. It is merely one of the "ghosts" conjured up by some people by way of excuse for failing to understand the case.

This will be rendered clearer by considering the cases of instability cited by those who believe that both aërial machines and submarines are equally liable to dive uncontrollably.

The case of Lilienthal has already been explained.

The case of the aëronaut who was killed last summer in San Francisco by falling with his broken aëroplane some 2,000 feet was in no way similar to Lilienthal's case. The San Franciscan aëronaut caused his aëroplane to dive downward edgewise, at a very steep angle, in order to acquire the velocity necessary for manœuvering.

After having acquired high velocity in his descent of some hundreds of feet he steered his machine to move horizontally. The great moving inertia due to the velocity of his descent was thus suddenly thrown on his wing arms, and because they were very far from being strong enough to endure the excessive sudden strain, they gave way, and the aëronaut with his broken machine was precipitated to the earth.

The submarine catastrophes cited are those of the English *A.8* and the French *Farfadet.*

It is remarkable that the eminent gentlemen who dis-

coursed before the English Society of Naval Architects, last summer, on the cause of the loss of these vessels attributed it to the untimely and improper use of the diving rudder instead of noticing what was clear to almost everybody else. These same gentlemen alluded to the fact that in the case of *A.8* the main water ballast tank, of 15 tons' capacity, was practically filled at that time by 9 tons of water, leaving 6 tons' volume of empty space.

The captain of the trawler—to avoid ramming, which at high speed the *A.8* turned rapidly to pass under the trawler's stern—testified that as the submarine moved around the curve she laid down on her side forcing her conning-tower under water, through the open hatch, on the top of which the water poured, causing the boat to go down by the head and disappear. The centrifugal force due to the boat's rapid motion in a circular curve caused the water in the tank to move to the outside of the curve and upset the boat.

THE CASE OF THE FRENCH SUBMARINE

Farfadet was practically similar, excepting that in her case there occurred a change of speed or inclination that caused the water in her partially-filled tank to move to its forward end, thus causing the common center of gravity of the boat and the water in its tanks, to move far enough forward to force the forward part of the boat under water. This unexpected manœuver, combined with her speed, forced the top of her turret under and she took enough water on board to send her to the bottom.

Evidently it is an important, yet a very simple matter, that the center of gravity of both aërial machines and submarines should be held immovably in one place, and that these centers should be at a sufficient distance beneath, exactly beneath, the center of support or buoyancy.

It will surprise most people interested in aëronautics to learn that the practicability of flight with engine-driven aëroplanes was demonstrated beyond question over thirteen years ago by Mr. Phillips, a distinguished English military officer; although for some reason he did not appear to appreciate his own work nor follow the plain course which his success clearly indicated.

As far as my knowledge extends he was the first, or one of the first, to attach importance to air rarefaction over a bird's wings, and to direct attention to the fact that the albatross's wings are held flat in the fore and aft direction when it soars horizontally. See "Engineering," London, August 14, 1885, and March 10, and May 5, 1903.

Mr. H. C. Vogt explained the function of air rarefaction on the lee side of ships' sails, and the forward faces of the blades of air propellers, in "Engineering," London, August 14, 1885, and September 22, 1888; but no one, so far as I am aware, even suspected that air rarefaction over a bird's wings, instead of being merely a help or even a considerable help, as Phillips believed, was the main factor, in fact almost the only source of support for all flying animals, when they are in full flight.

Thirteen years have passed since Mr. Phillips proved

the practicability of aëroplane flight, not by causing his apparatus to lift itself with a man to direct it, but by proving that a certain area of aëroplane surface, even though unsuitably arranged, did actually lift about 39 per cent. more total weight than anybody up to that time, including all the authorities, would admit to be within the range of possibility.

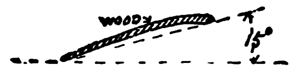
His machine was not quite large enough and the power was inadequate. Nor is it probable that he expected that it would also lift himself, but that same machine would have given much better results had there not existed certain defects in the design that prevented the presence of the degree of rarefaction and consequent lifting power that would have been attainable had these defects been eliminated. The vertical supports for his aëroplanes were nicely arranged to conduct air from above into the places where, with proper precautions, a much more intense degree of rarefaction would have existed.

The important point that his experiment developed was that, with suitable conditions, some other force besides those recognized by the authorities was in action, and in effective action, although he failed to fully appreciate it.

Had his machine been a little larger, with about double the power provided, even of the same unsuitable, heavy kind, he could certainly have flown in the air, and he would not have been compelled to wait as long as I did, twenty years, after providing the first successful submarine boat, before the value of his invention was even partially recognized.

Mr. Phillips's machine is described in "Engineering," London, March 10 and May 5, 1893.

It consists of a Venetian-blind-shaped frame containing 50 slats or "sustainers" 1½ inches wide and 22 feet long, fitted 2 inches apart in a frame 22 feet broad and 9 feet 5 inches high. The sustainers have a combined area of 136 square feet; they are convex on the upper surface, and concave below, the hollow being about one sixteenth inch deep.



Phillips's Aëroplane
1½ inches wide

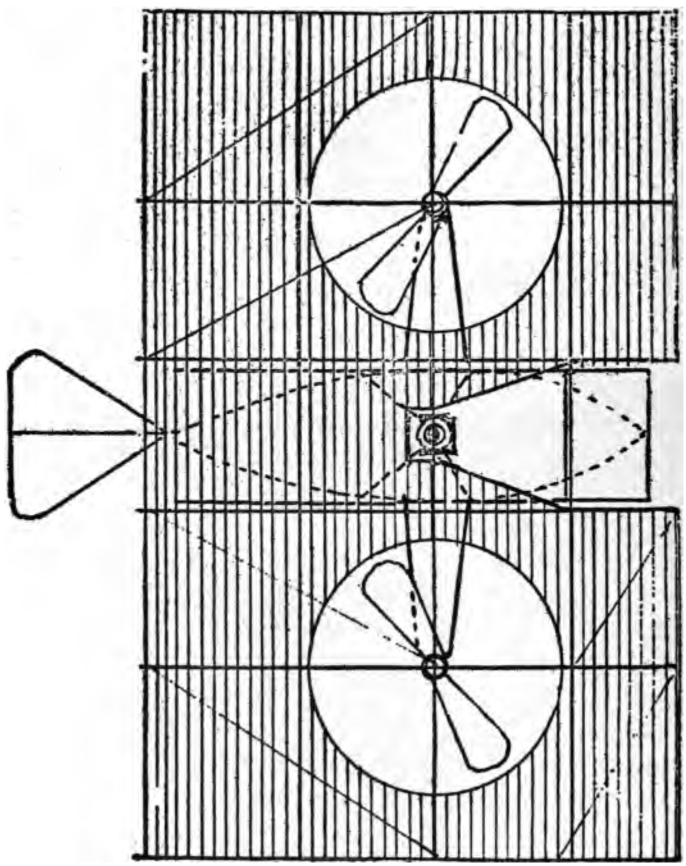
The frame holding the sustainers is set up in a light canoe-shaped carriage, composed principally of two bent planks like the two top streaks of a whale boat, and being 25 feet long and 18 inches wide, mounted on three wheels one foot in diameter, one in front and two at the rear.

The vehicle carries a small boiler with a compound engine, which works a two-bladed aërial screw propeller revolving about 400 times per minute.

The fuel is Welsh coal. There is said to be no attempt to provide exceptionally light machinery. The weights of the various parts of the machine are, approximately, carriage and wheels, 60 lbs.; machinery with water in boiler and fire in grate, 200 lbs.; sustainers, 70 lbs.; total weight, 330 lbs.

The machine was run on a circular path of wood with a circumference of 628 inches (200 inches diameter), and to keep it in position (preventing erratic flight) wires were carried from various parts of the machine to a central pole.

Still further to control the flight, which there is no means of guiding, the machine is not of sufficient

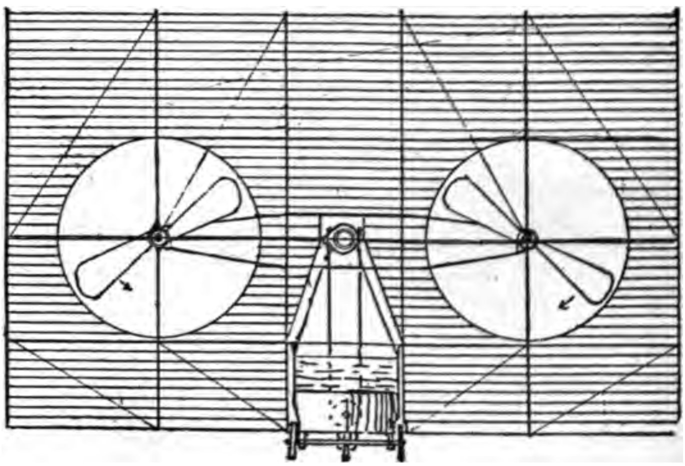


Plan of Holland Aëroplane at Rest, Propeller Horizontal

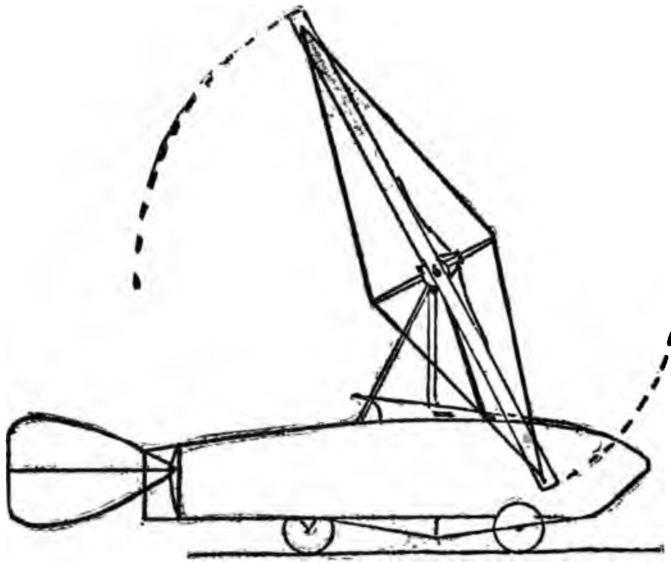
size to carry a man, the forward wheel is so balanced that it never leaves the track, and therefore serves

as a guide, carrying some 17 lbs. of the weight, the remainder being on the hind wheels.

On the first run 72 lbs. dead weight were added, making the total lift 402 lbs. As soon as speed was gotten up and when the machine faced the wind, the hind wheels rose some two or three feet clear of the track, thus showing that the weight was carried by the

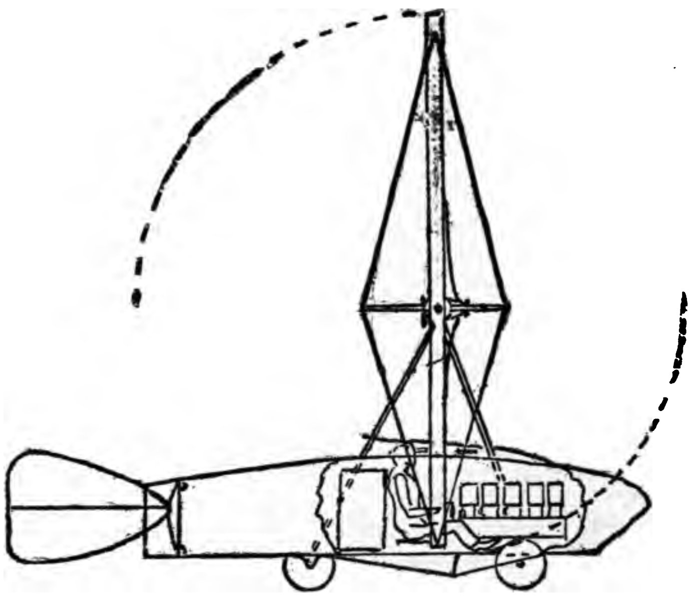


air upon the Venetian-blind sustainers. A second trial was made with the dead weight reduced to 16 lbs. and the circuit was made at a speed of about 28 miles per hour (2,464 feet per minute), with the wheels clear of the ground for about three fourths of the distance. That the machine can not only sustain itself, but an added weight, was demonstrated beyond all doubt, even under the disadvantages of proceeding in a circle, with the wind blowing pretty stiffly.



Planes at 35°, Rising from Level

It is possible that Mr. Phillips was discouraged by the opinions of those persons who "proved" that for successful mechanical flight an engine was required which, with its supply of coal and water for even a very brief performance, should weigh no more than 5 lbs. per horse-power, whereas available engines weighed many times more than 5 lbs. per horse-power, and more probably 60 lbs; but apparently he was not aware of the existence, at the time he made his experiment, of internal combustion, hydrocarbon engines that need not have weighed more than one fifth of the weight of his motor, with its supplies. A specially designed Brayton engine would have suited

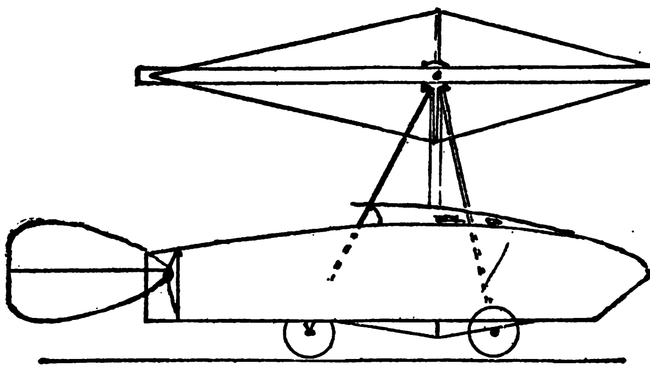


In Full Flight

the work fairly well. At the present day we can avail ourselves of the wonderful development of automobile engines, due chiefly to the genius of Frenchmen, and of the incomparably better material for both machine and motor that is now available. We have also discovered that the threatened dangers and difficulties of aërial navigation are chiefly imaginary, and that actual flight, whether of bird-like navigation or aëroplane, instead of being a complex problem to be approached cautiously and carefully, is, in fact, simplicity itself.

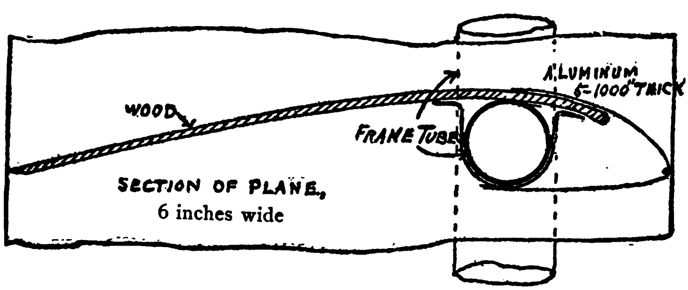
Having already described and illustrated an appara-

tus for bird-like flight, we may now consider designs for an aëroplane machine to be operated by an auto-



Aëroplane Machine at Rest

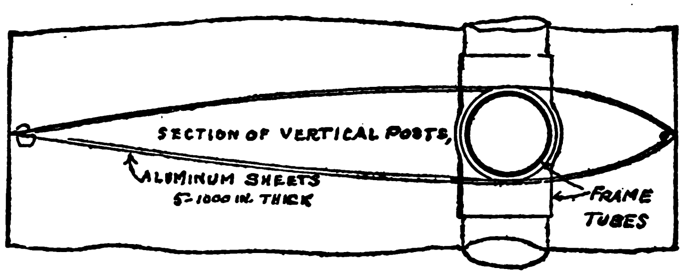
mobile engine, not a specially built engine, but one of the ordinary kind, weighing say 9 lbs. per horse-power. Successful engines have been built less than



one third of this weight, but we shall act wisely in considering nothing that is special and expensive, but only the kind that is already well-tried and in every-day use.

We shall design our machine and examine its carrying power and endurance and radius of action. The necessary lifting power is the first point of consideration, and

it may be noted that opinions differ a good deal regarding what one horse-power can lift with the aid of a suitable air propeller. The estimates vary between 35 lbs. and 85 lbs., depending on the perfection of the apparatus and on whether the experimenters took the ver-



tical movement of their apparatus into account; but it is generally recognized that one horse-power can balance 60 lbs. weight when there is no vertical movement of the machine.

Messrs. Dahlstrom and Lohman, engineers, Copenhagen, in September, October and November, 1887, experimented with propellers working in air and operated by the engines of a launch which was also fitted with a propeller in the ordinary position, working in the water, when a comparison of the relative efficiency of the propellers was required. They determined that when the air and the water propellers were similar in the proportion of pitch to diameter, with proportionate surface, that the air propeller should have about five times the diameter of the propeller working in the water in order to obtain the best results. They found further that when each propeller was driven at exactly the same speed of revolution as the other, and by the same engine, that the thrust exerted by the air propeller slightly exceeded the thrust delivered by the propeller working in water. The air propeller was of light material. The water propeller was of the ordinary metal construction.

Therefore our air propellers may be expected to afford 60 lbs. lift without ascensional speed and that the weight lifted will be decreased as the vertical speed increases.

We shall design our machine practically on the same model as the one described in "Cassier's Magazine," New York, February 19, 1893, provide it with a 25 horse-power automobile engine, which will afford a total lifting power, at 40 lbs. per horse-power, of 1,000 lbs., leaving a margin of 20 lbs. per horse-power, equals 500 lbs. for ascensional power.

In the design for an aëroplane machine as illustrated,

the aëroplanes are set in a frame so as to resemble a great Venetian blind, which is pivoted at the middle of its vertical length in order that it may be set vertically or horizontally. When the machine is at rest the aëroplane frame lies horizontally, having the axes of the two propeller wheels shown standing vertically. The propeller wheel bearings are carried at the ends of a trussed frame that forms part of the aëroplane frame structure, this trussed beam being carried on bearings at the tops of two connected A frames that rise from the body or car of the machine.

The body, or car, rests on three wheels, two forward and one aft, under the floor of the car. The after wheel is adjusted on a vertical spindle so that it may serve to steer the machine when it moves on a roadway.

When the machine starts on its aërial trips, the aëroplane frame lies horizontally and both propeller shafts stand vertically.

When they are revolved rapidly, with the full power of the engine, the machine rises slowly in the air, and it must be permitted to rise until it has attained an elevation sufficient to be clear of all obstructions.

The aëroplane frame is then slowly revolved on its horizontal axis, thus inclining the axes or the propeller wheels toward the horizontal, and reducing their lifting power. When the inclination reaches about 45 degrees the lifting power of the propellers will be sufficient to balance the dead weight of the machine, and the aëroplanes then coming into action, will develop a lift depending on the speed of the machine.

Mr. O. Chanute's tables indicate that at an inclina-

tion of 45 degrees of the aëroplanes the lift and drift force are each two thirds of the total pressure. Therefore at this inclination the drift force applied will develop a considerable lifting force, by means of the aëroplanes. But two thirds of the total lifting power of the engines and propellers are competent to balance the total weight without the aid of the aëroplanes. At the same time they develop a lift depending on the speed with which they are moved horizontally.

It follows that the machine would continue to rise if held under these conditions, but when a great elevation is not required the operator will continue to raise the aëroplane frame until it stands vertically and all the weight is carried by the planes. The propellers and engines will not then be required to do any lifting, but only to exert what power may be required for propulsion.

When the operator desires to alight he will simply reverse this operation, and because the speed of the engines will be under control he can hold his machine still in space, whether in a calm or in a storm, and also alight without shock.

It therefore appears reasonable to expect that, possessing the power to obtain horizontal motion as soon as obstructions are cleared, and to face the wind, that the course of the machine in rising would be vertical, should there be any wind blowing, and then quickly changing to horizontal motion in the direction the operator desires, and that the trace of his course when alighting, if exhibited on a chart, would be exactly similar but in the reverse direction, facing the wind if any exist during his descent.

The speed of the machine required when the planes afford full support, at say 6 degrees elevation, may be determined thus:

Total weight, 1,000 lbs.

Total plane surface, 500 square feet.

1,000 pounds divided by 500 equals 2 lbs. lift per square foot. Proportion of lift at 6 degrees elevation equals 0.206, proportion of drift at 6 degrees elevation equals 0.0217; 1,000 lbs. weight divided by 500 square feet equals 2 lbs. per square foot lift wanted; 2 divided by 0.206 equals 9.7 lbs. wind pressure. And this pressure is exerted by wind at 44 miles per hour. The drift force required for 500 square feet of aëroplane at 6 degrees inclination, equals 500 × 0.0217, equals 10.85 lbs. Add 50 per cent. of this for friction of frame and body of car, 10.85 × 1.5 equals 16.275 lbs. total drift force.

Speed required to afford 2 pounds per square foot lift equals 44 miles per hour, equals 64.53 feet per second, 64.53 × 16.275 equals 1.050 foot pounds per second, 1.050 divided by 550 equals 1,727 horse-power.

This calculation shows that when the machine is traveling through the air at a speed of 44 miles per hour, having the aëroplanes inclined 6 degrees to the horizon, the actual propulsive power employed will amount to only 1.724 effective horse-power. But engines of 25 horse-power are provided; that is, 14 times more power than will be required at 44 miles speed.

The speed being in the proportion of the cube root of the power employed, cube root of 14, 241 × 44 miles equals 106 miles speed if the friction of the car and frame increases only in the same proportion as the drift

force. But as it is probable that it will increase more rapidly the speed with 6 degrees inclination of the aëroplanes will be reduced from 106 miles possibly to 100 or even to 95 miles per hour.

But it was shown above, when considering the bird-like machine, that the inclination of the albatross's wings, if they were inclined, could not have been greater than 45 minutes of arc. Therefore, it follows that 100 miles per hour is by no means the speed limit of our aëroplane.

We may now consider its radius of action when carrying only the weight of oil fuel mentioned above, 150 lbs.

For the work of direct lifting 15 horse-power is required, but for horizontal motion at a speed of 44 miles per hour, it has been shown that only 1.7 horse-power will be exerted continually.

When the engines are developing their full power, 15 horse-power, they are working under the most economical conditions and they require only one tenth gallon of oil fuel per horse-power, per hour, but when they are developing only 17 horse-power they do not work nearly so economically, requiring under those conditions about one fourth gallon per horse-power per hour.

The quantity of oil provided was 150 lbs. weight, equals 20 gallons.

1.7 horse-power multiplied by 0.25 equals 0.425 gallons per hour; oil carried, 20 gallons divided by 0.425 gallons equals 47 hours supply of oil fuel.

47 hours multiplied by 44 miles speed equals 2,068

miles radius at 44 miles speed; that is, our machine could start from one of the explorer's stations in Northern Greenland, pass over the North Pole and return, photographing everything on the way, or it could, in one trip, cross the Atlantic Ocean between St. John's, Newfoundland, and Ireland.

When the machine starts from a level road, along which it can run at good speed, much more elevating power will be developed than when operated as described above, but the aëroplanes must be inclined at a greater angle than 6 degrees.

Suppose they are inclined, at starting, say 20 degrees from the horizontal position by inclining the plane frame 20 degrees from the vertical position.

The proportion of drift force for 20 degrees inclination is 0.228. Add one third to this for resistance of car and frame.

0.228 plus 0.076 equals 0.304 lbs. drift per square foot.

0.304 × 500 square feet of aëroplane surface equals 152 lbs. total drift force.

The engines are of 25 horse-power, equals 13,750 foot lbs. per second.

13.750 divided by 152 equals 90.46 feet per second, equals 61.67 miles per hour. This speed affords a wind pressure of 19 lbs. per square foot.

The proportion of lift for 20 degrees inclination is 0.515, 19 × 0.515 equals 9.785 lift per square foot.

9.785 × 500 equals 4.892.5 lbs. total lifting power. If 2,000 lbs. of this force be applied to direct lifting, the remainder will be ascensional force.

By adopting this method of rising it is also evident that a much greater weight can be lifted and carried than by employing the method of direct lifting. Travel over a long distance will reduce the weight of oil fuel. Some things, such as mail-bags, may be dropped without injuring them, or by employing small parachutes, but unless the operator is favored by a strong wind against his direction of motion, when alighting, or by a convenient smooth surface of water, or an asphalted road, it will be difficult to come to rest without shock, if the total weight be not reduced to about what the engines and propellers can hold suspended in the air, probably 25×60 equals 1500 lbs.

The purpose of this paper being to present reasons for believing in the possibility of mechanical flight and to illustrate them with designs for two sets of apparatus which appear to be practicable, even though, like most new things, they will almost surely, in time, prove to have been only crude attempts, it will not be necessary to give more detail than is required to suggest means and methods to the engineers, who will soon accomplish their complete development and place at our service nature's great highway, the atmosphere.

VII

THE COMING DIRIGIBLE AIR-SHIP

BY CAPT. HOMER W. HEDGE

THE recent experiments with dirigible air-ships made by inventors in various countries have produced some appreciable results, and each success, each failure, provides an instruction or a warning. These experiments, made by such men as the Wright Brothers of Dayton, Ohio; Leo Stevens of New York; Prof. Manly of the Smithsonian Institute at Washington; Count Zeppelin of Germany, and M. Lebaudy of France are watched by the public almost as eagerly as by inventors.

The great impetus given to the study of aërial navigation by the Aero Club of America, while not yet productive of many actual results, is paving the way for them. It should be remembered that the balloon is the one tangible proof that man can rise to heights through the air without the aid of wings, as certainly as he can travel through the water independently of fins.

The Aero Club of America is intensely interested in the solution of the problem, and it has always extended a warm welcome to the many inventors and aëronauts

of the United States, or visitors to this country from abroad. The liberal interchange of ideas has been commendably cosmopolitan, liberal, and free from jealousy, and in the face of thousands of disappointments I believe the belief in a near success is quite general.

At present the balloon offers to the wealthy a delightful and adventurous pastime, not wholly without actual benefit, for the inhalation of rarified air is both exhilarating and invigorating, and it certainly affords a "higher" education, for I defy any one to make an ascension without getting a new and impressive conception of the immensity of the universe, and his personal insignificance.

For other than commercial purposes, I believe the development of the balloon along practical lines will be rapid. It is primarily a question of material, shape, and motive power. Within ten years' time we shall have safe, and genuinely dirigible balloons, capable of continued long-distance flights, available for pleasure, for the benefit of lung troubles, for meteorological observations, and for war purposes.

If the balloon of the present be regarded from a commercial standpoint, it has no appreciable value. Its bulk, construction, cost of manufacture, gas and maintenance, added to the fact that the direction of its flight cannot be controlled, combine to convince the business man that this talk of aërial navigation is a question not likely to be solved in time to suit his particular needs. He does not expect to live to see a real air-ship, laden with freight, or any great number of

passengers, navigating between given points, and arriving at its destination on scheduled, or any other sort of time. The well-known and proven methods of travel and transportation by land and water are good enough for him. Faith in these is certainly more justifiable now than ever before, such remarkable progress having been made of late in increase of power and economy in its production, resulting in the electric locomotive, trolley, automobile, turbine engine and motor boat.

But the air-ship is as sure to come as death and taxes. The greatest drawback to its arrival up to the present time has been that inventive minds have not been greatly attracted to it because of the great expense attached to experiments on a satisfactorily large scale; with no certainty of much money being made out of it in any event. To-day so many men of means are convinced that the problem can and will be solved, that, when an inventor has evolved and can submit a plausible plan, it is not a very difficult matter for him to find those who are able and willing to bear the expense of putting it to the test.

For arousing present public interest in the subject, the Aero Club of America has chiefly to be thanked. The numerous balloon ascensions made by its various members, together with their recorded observations and experiences, have resulted in reducing the risks run by aëronauts, in making us more familiar with the varying conditions of the atmosphere, as well as better informed as to the difficulties to be overcome.

So long as the material of which the dirigible bal-

loon is constructed is as perishable as at present, no great speed can be hoped for nor attempted with safety, however powerful the motive power may be. The familiar gas-bag is uninjured in a high wind because it is a part of it, borne along at its own pace, and offering no resistance; but if it had to be made to travel *against* a high wind things would be very different.

The dirigible balloon will materially increase its usefulness, but the practical air-ship will, I feel sure, be made of "sterner stuff."

Considering the short time since the subject has been seriously studied in recent times, in this country, it would seem that more rapid progress toward the true solution of aërial navigation has been made here than elsewhere. While the first real advance, and the actual aërial transportation of people will probably be by means of the reënforced and steerable balloon, it will, in all likelihood, be only a means to the end; and, as motive power and velocity of propulsion are increased, by inventive evolution there will be realized the practical "heavier-than-air" flying machine, or aëromobile.

Once found, the simplicity of the solution will be certain to astonish us. Mere shape determines whether iron shall float or sink.

The interest in aëronautics is increasing daily, and with the international balloon race for the Gordon Bennett Cup, the exhibits and races at the Jamestown Exposition, and the growing number of aëro clubs, universal attention will be centered, this year, on the United States, and the expectation of the world will be that good must come of it. Good fellowship, and

the cementing of friendship is certain, and it will be strange if genuine advancement does not result.

Personally, my interest in the question of aërial navigation has been intensified by reason of the projected "Universal Astronomical Society," which will aim to bring together more closely the astronomical and kindred societies of the world, for the better and speedier verification of alleged discoveries; the collection, classification and dissemination of data, etc. When aërial navigation is an accomplished fact, it will be possible to take observations of the heavens through an atmosphere unobscured by clouds; a point, at all times, of the highest importance, but especially so at critical moments during rare conjunctions and eclipse.

VIII

THE VERTICAL SCREW OR HÉLICOPTÈRE

BY PROF. WM. H. PICKERING
Harvard University

FLYING machines may be divided into three classes: *a*—those with flapping wings, whose origin is prehistoric, *b*—the aëroplanes, invented in the last century, and *c*—those dependent on the action of one or more vertical screw propellers. This last form, it is said, was invented by Leonardo da Vinci, who made some successful paper models about the year 1500. The writer first became interested in this form of flying machine a little over thirty years ago, when he constructed some models with feathers, cork, and whalebone, that flew successfully to the ceiling.

In 1880 he made measures of the speed, lift, and power consumed by various small fans; and in 1881 a 40-inch fan, driven by power, was tried. With this it was shown that the air currents set in toward the fan, not only from the front and sides, but also from the rear, gradually increasing in intensity until we reached the surface of a cone, having the center of the fan for its apex, the shaft of the fan for its axis, and an angle at the apex with the axis of 45 degrees. At the surface of this cone, the direction of the air cur-

rents suddenly reversed in direction, and rapidly increased in strength, attaining a maximum shortly before the axis was reached. In the line of the axis, and near the fan, the current again sometimes reversed setting toward the center of the fan.

In 1895 an extended series of observations was made on fans ranging from 18 inches to 12 feet in diameter. Four different testing machines were employed for determining the speed of rotation, the lift, and the power absorbed. The latter ranged from about 0.001 of a horse-power for some of the 6-foot fans up to 4.3 horse-power for the larger sizes. The general accuracy of the theoretical formulæ for fans was confirmed, but it was found that the exponents of the speed were about one-tenth of a unit higher than their theoretical values.

Attention may here be called to the fact, which, although mathematically obvious, does not seem to be generally known, that the lift of a fan is not proportional to the work done upon it. The lift is a function of the work and diameter, and the three quantities should all be given in order to make the observation of any value.

Thus, with a 6-foot fan, the writer has obtained a lift of 254 lbs. to a horse-power. If nothing more were said, this result would seem very encouraging for aërial navigation, and much better than the published results of other experimenters, who state that they have obtained lifts of only 30, 40, and 50 lbs. When, however, we go into details, and explain that the power employed was 0.0013 of a horse-power, and the lift

was just 1/3 lb., the importance of the result is seen to be negligible. Nevertheless, it is of interest as showing how simple a thing it is for a small light animal, such as a bird, or an insect, to fly, as compared with the difficulty encountered by a large heavy animal such as a man.

When it comes to practical units, the writer has with a 12-foot fan and one horse-power of work, obtained a lift of 48 lbs. In 1902, with a 20-foot fan, and an electric motor, furnishing 20 horse-power, he obtained a steady lift of 430 lbs. The lift is here reduced, it will be seen, to only 21.5 lbs. to the horse-power. The larger the fan, the more efficient, but the more it will weigh.

In these last experiments the electric motor was mounted on a couple of steel floor beams, which were supported on knife edges, the whole being housed to protect it from the weather. The shaft of the fan projected through a hole in the roof, and the fan itself was mounted just above the top of the building. When not in use, the fan could be removed and stored. The general appearance of the apparatus is shown in Fig. 1.

In 1903, in order to test the applicability of fans to flying-machine construction, two fans were mounted side by side on a light steel framework, power being transmitted to them through long steel rods, furnished at both ends with universal joints. The power was generated by two small electric motors and transmitted to the rods by balanced pulleys. On starting the fans, the machine rose rapidly in the air through a height of 3 feet, which was as far as the cord holding it to the

floor would permit it to go. A basket of steel wire was next attached to the middle of the frame, and this was also carried up, the machine and basket together weighing 3 lbs. A small white rabbit, weighing 1 lb., was next placed in the basket and sent aloft. In this position he was photographed; see Fig. 2. The fans are revolving so rapidly that they are not well shown. The total lift of the machine with this power was found to be 4.5 lbs. It is believed that this is the first time that a living animal was ever carried up and maintained in the air by a purely mechanical flying machine.

The same year a lady's tricycle was procured, the small sprocket removed from the rear axle, and caused to drive a fan mounted on a horizontal longitudinal shaft. With a fan 6 feet in diameter, a speed of 10 miles per hour was readily secured on a smooth wooden floor. Various forms of fans and propellers were tested. The best of them gave an efficiency of about 70 per cent. The efficiency was shown to increase with the size of the fan, but the speed of rotation diminished. Therefore the maximum speed was attained with fans of moderate size. This machine and propeller were exhibited at the Mechanics Hall in Boston, and again at the last exhibition of the Aero Club in New York.

Such a tricycle would be of little use upon the roads on account of danger from the blades of the rapidly revolving propeller, which at high speed are almost invisible. With increase of resistance the efficiency of the fan rapidly falls off. Such a fan might

be used on boats in shallow waters; and some experiments of this sort have already been made. It is thought, if applied to an ice boat, interesting results might be obtained.

IX

THE BALLOON IN SCIENCE AND SPORT

By A. Lawrence Rotch

ALTHOUGH the principle "heavier than air," as exemplified in the aëroplane, is probably the true solution of the practical flying machine, it must be admitted that, up to the present time, the balloon alone has enabled man to rise freely in the air, or to navigate it to some extent.

The use of balloons may be divided into three categories: first, the exploration of the air for scientific purposes, second, their application to military purposes or sport, and third, the attempts to navigate the air, independently of the wind, by some motive power which they carry. The first two topics only will be considered in this paper.

It should be remembered that the first scientific balloon ascension was made in England in 1784 by Dr. John Jeffries, a Bostonian residing in London, accompanied by Blanchard, a French professional aëronaut; and that the following year they crossed the English Channel in a balloon and landed in France.

In America, St. Louis has been the center of ballooning, and it was from this place that John Wise, in

1859, made one of the longest balloon voyages, landing, after nineteen hours, at Henderson, New York, a distance of about 870 miles in a straight line from St. Louis. Here, also, Prof. H. A. Hagen, in 1887, rose 15,400 feet, which is probably the greatest height yet reached by man in this country. Prof. Hazen later tried, although unsuccessfully, to obtain automatic meteorological records at a greater height by means of a balloon provided with self-recording instruments, which was set adrift from St. Louis in 1893, following a method that had been used in France the previous year.

The height to which man can ascend in a balloon and live, even when aided by the respiration of oxygen, is limited to about seven miles, but the *ballons-sondes,* or balloons which carry only self-recording instruments, enable the temperature to be obtained twelve miles or more above the earth, as ascertained by the record of the barometer. The first application of the kite to secure automatic and continuous records of the temperature at lesser heights in the free atmosphere was made at Blue Hill Observatory, near Boston, in 1894. Later, cellular kites supplanted the flat ones; wire, manipulated by steam-power, was substituted for cord as a flying line, and an instrument was constructed to record, besides the temperature, the barometric pressure, relative-humidity and wind-velocity. Several hundred kite-flights have been made at Blue Hill to an extreme height of more than three miles and the meteorological conditions within this region thoroughly investigated. This method of sounding the air, as devel-

oped at Blue Hill, has been very generally adopted by the meteorological services of this country and Europe.

The fact that the atmosphere has no boundaries, and can be preëmpted by no nation, makes its exploration a truly international undertaking, and so the International Committee for Scientific Aëronautics, which was formed in 1896, with the object of obtaining meteorological observations in the free air, has systematized and published these observations.

Balloon ascensions and kite-flights have taken place for several years, on a certain day every month, at many European stations and there have been coöperative kite-flights at Blue Hill, and recently at the new observatory of the United States Weather Bureau on Mount Weather, Virginia. The first observations at great heights above the American continent were made by the writer at St. Louis in 1904, and, whereas with kites a height of about three miles only is reached, the rubber balloons rise sometimes to a height of ten miles before they burst, when, by means of a parachute, the attached instrument is borne gently to the ground, where it is usually recovered. Fifty-five such *ballons-sondes* were sent up from St. Louis in 1904, 1905, and 1906, and all but three were found and returned to Blue Hill Observatory on payment of a small reward, most of them falling a hundred miles or more to the east or south of St. Louis. From the records of the barometer and thermometer the heights and corresponding temperatures were ascertained, the lowest temperature recorded being 110° Fahr. below zero at a height exceeding 9 miles, in January, 1905. By classifying the

ascensions according to altitude the drift and speed of the air currents above St. Louis are indicated, which, in view of the wise selection of that place as the starting point of the next Gordon Bennett Cup race are of especial interest. Eight balloons which traveled at the average height of 6000 feet moved from an average direction 11° north of west at a speed of 25 miles per hour; thirteen balloons traveled at an average height of 12,000 feet from 3° north of west at the rate of 38 miles per hour; sixteen balloons, at about 20,000 feet, went from 5° north of west at the rate of 56 miles per hour, and nine balloons at about 26,000 feet, drifted from 9° north of west with the speed of 47 miles per hour. All these data relating to the upper air currents are corroborated by the trigonometrical measurements of clouds which were made at Blue Hill several years ago.

Since the racing balloons will probably not rise higher than a mile, it may be expected that those which start from St. Louis next October will travel toward a direction slightly south of east at a speed of approximately 25 miles per hour.

On any particular day it is possible that the drift of the upper air currents may differ from this. For instance, a *ballon-sonde*, which, on November 23, 1904, reached an altitude of 7600 feet above St. Louis, traveled 55 miles at the rate of 51 miles an hour, while another balloon the next day went nearly three times the distance in the same southeasterly direction. The smallest velocity was shown by a balloon on May 17, 1906, which, though it rose to an extreme height of

14,700 feet, traveled only 15 miles northeast at a speed of but 11 miles an hour. In contrast to this, two balloons, which reached an altitude of about 7 miles on consecutive days in November, 1904, traveled at an average speed of 100 miles an hour, one going 280 miles east, the other 235 miles south-southeast. As this represents the average velocity in both the highest and lowest air strata, the velocity in the former probably greatly exceeded 100 miles an hour, and such velocities of the upper air currents are shown by the measurements of the drift of cirrus clouds at Blue Hill to be not unusual, over the United States, in winter.

Assuming that the mean temperature at St. Louis during October is 59° Fahr., the temperature at a height of two miles will be about 35°, and at four miles about 15°. At the great altitudes attained by the unmanned balloons the temperatures are very low, even in summer. For example, in July, 1905, 75° Fahr. below zero was recorded at a height of less than 9 miles above St. Louis.

By means of kites and balloons the atmosphere over the Atlantic Ocean has been explored by expeditions sent out by the Prince of Monaco, in coöperation with Prof. Hergesell, and also by M. Teisserenc de Bort and the writer. The fact that kites might be used at sea, independently of the wind conditions, by utilizing the motion of the steam-vessel, was first demonstrated by the writer in 1901; and kites have been extensively employed by both the expeditions mentioned. By means of pilot-balloons, whose drift was measured either from a base-line on the lee-shore of islands, or

by following the balloons with the steamer, the direction and speed of the wind was obtained at much greater heights than was possible with kites, and within the region of the northeast trades almost all the balloons launched by the Franco-American expedition showed the expected south or southwest return-trade above the height of two miles. A method of using the *ballons-sondes* at sea having been devised by Prof. Hergesell and employed on board the Prince of Monaco's yacht in 1905, it was adopted by M. Teisserenc de Bort and the writer on the steam-yacht *Otaria* during a cruise across the equator last summer. Two rubber balloons are coupled tandem and when one bursts, after reaching the maximum height, the other sinks slowly until the instrument and exploded balloon touch the water, above which it floats, supporting the instrument and guiding the vessel to the spot. Of twenty-two such balloons liberated by our expedition but seven were lost. The existence of the northwest current above the southeast trade was demonstrated, and the unexpected fact revealed that in summer at ten miles above the thermal equator a temperature about 100° Fahr. below zero reigns, which is lower than that found in winter at the same height above the north temperate regions.

In this way we are gathering information about the conditions of the free atmosphere in various parts of the world, which is not only necessary to confirm theory, but, so far as it relates to the lower mile or two of the aërial ocean, will be of practical utility in its navigation, whenever that shall be realized.

Ballooning as a sport has only recently come into favor, and may be said to date from the foundation of the Berlin Aeronautical Society in 1881, whose early work was mostly scientific. About ninety ascensions have been made by its members, including an ascent by Professors Berson and Süring to the height of 34,000 feet; an ascent by Glasher, in which he claims to have risen to 37,000 feet, the greatest altitude ever reached by man, and a voyage of 53 hours, which is the longest time a balloon has remained in the air, by the Wegener Brothers.

A balloon corps is attached to the armies of most European nations for the purpose of reconnoitering and telegraphing or signaling with captive balloons; and in the German army a kite-balloon is employed which is independent of the wind. The French Aero Club was founded in 1898, and, in the land where the balloon originated and had always been popular, the club has achieved success. With its coöperation, a series of competitions were held during the Paris Exposition of 1900 which did much to demonstrate the efficiency and safety of ballooning. During the summer 158 ascensions took place from the aërostatic park of the Exposition without any accident, although on one day there ascended twenty-six balloons holding 20,000 cubic meters of gas. The competitions were of various kinds but related chiefly to the longest time in the air, the greatest distance traveled or the greatest altitude attained. In order to allow small balloons to compete there were races in which the aim was to land as near as possible to some point, chosen beforehand by each

aëronaut, within twenty-five miles of Paris, and the skill shown in utilizing the winds at different heights and in making use of the guide-rope, was shown by one aëronaut landing within half a mile of the place that he had designated. In the final long-distance race Count de La Vaulx landed in Russia after a voyage of 1200 miles, which is probably the longest one ever made in a balloon.

In 1904 Count de La Vaulx visited the United States with the idea of organizing an aero club, and as a result the Aero Club of America was founded the next year. At a meeting in Paris in 1905 to federate the aero clubs, the writer represented this, the youngest of them, and the figures of the gas used in the various countries during the preceding year which were adopted as the basis of representation in the federation, are here given as showing the popularity of ballooning abroad. It may be remarked that in some cases the gas used by the military balloons has been included. Since the quantity of gas required to fill an average balloon is about 1000 cubic meters the approximate number of ascensions may be calculated from the following figures:

France	310,000	cubic meters
Germany	202,000	" "
Belgium	67,000	" "
Italy	33,000	" "
Great Britain	20,000	" "
Spain	20,000	" "
Switzerland	7,000	" "
United States		

The past year has witnessed three notable aëronautical sporting events. The Gordon Bennett Cup race from Paris last October was won, as is well known, by our countryman, Lieutenant F. P. Lahm, who, being driven across the Channel, was obliged to land in England after covering but 402 miles.

A similar event, which occurred later in the same month, was an international balloon race from Berlin for cups offered by the German emperor and by the Berlin Aëronautical Society, which was celebrating its twenty-fifth anniversary. In this contest no English, French or American balloons competed, and the seventeen starters were mostly German. Owing to light northwest winds none of them landed far beyond the German frontier and, although some of the balloons remained twenty-four hours in the air, they made a circuitous course. The first prize, however, was not won by the balloon which traveled the furthest distance but by the one which showed the best relation between its cubic contents and the distance. Therefore the prize went to a Berlin balloon which landed only 212 miles in a direct line from Berlin, while the Munich balloon landed 250 miles away, because the first balloon showed a ratio of 0.58 kilometer per cubic meter capacity and the second 0.31 kilometer.

The third noteworthy sporting event was the passage of the Alps last November by a balloon manned by Signori Usuelli and Crespi. The former aëronaut, early in the summer, met with an accident when his balloon fell into the Adriatic and drowned two of its occupants. In the present voyage the start was also

made from the Exposition grounds at Milan, and Lake Maggiore was traversed at a height of 16,000 feet. The balloon passed over Monte Rosa and high above Mont Blanc at an altitude of 29,000 feet, where the temperature was 29° Fahr. below zero, and the aëronauts were only kept alive by inhaling oxygen. A landing was effected near Aix-les-Bains, after traveling about 200 miles in a little more than four hours, and thus the oft-attempted feat of crossing the main Alpine range was accomplished, and the Royal Cup "Margaret of Savoy" won for the first time. It may be remarked, however, that in 1849 a manned balloon went from Marseilles to Turin.

X

A BALLOON TRIP FROM CINCINNATI, OHIO, TO SOUTH CAROLINA, IN APRIL, 1861

By Prof. Thaddeus S. C. Lowe

THE significance attached to my early balloon work can be better understood if my reader compares and considers it with the kite-flying of Benjamin Franklin. So much does the modern scientific world think of Benjamin Franklin and his simple kite, that one of the imposing statues of the World's Columbian Exposition represented him in the act of flying the kite, and it occupied the post of honor at the main entrance of the Electrical Building. It seemed a small and insignificant affair, and yet it was that "kite-flying folly" that has led to the discoveries which have made possible the telegraph, submarine cables, telephone, phonograph, electric railways, and the thousand and one scientific and useful instruments and appliances of modern electricity. All these wonderful and useful inventions are the indirect result of that one little experiment of Franklin's, thus demonstrating the value of even small things, when directed for a scientific purpose by a scientific mind.

Few people understand the deep scientific interest

that was felt by Joseph Henry and many men of his intellectual stamp, in my balloon trip from Cincinnati in April of 1861. The trip was made purely in the interest of science. There was no monetary or other inducement in connection with it. In my observations of air currents I had become absolutely convinced of the existence, in the higher atmosphere, of a current which uniformly and almost invariably moved eastward, with but slight variations, no matter how diverse the surface currents might be. In order to test the existence of this current, over the ocean as well as the land, I planned the necessary machinery to carry on the work, and the trial of it so interested a number of the prominent eastern bankers and merchants that they offered to help sustain the expense, with a view—provided it was shown to be perfectly safe—to the inauguration of a balloon system which would convey information across the Atlantic in much less time than that occupied by the mail steamers.

In those days there was no telegraphic communication between the United States and Europe, the first Atlantic cable having failed, and the only way, therefore, of getting mercantile news across the ocean was by means of steamers. The merchants knew that the reduction by a day, or even, sometimes, of but two or three hours, in the time of the receipt of important news on business or other affairs would often make a difference to them of many thousands of dollars, enabling them to dispose of, or buy up, goods ahead of their competitors. This was the secret of their willingness to aid in sustaining the expenses of my earlier experiments. I was

ready to receive their help, but my object in the work was purely for the interests of science, and to further the organization of the Weather Bureau elsewhere spoken of, and which has since been accomplished on the lines I suggested, by the United States government.

I had already constructed the aërostat for my Atlantic journey. It was the largest one ever built, and has never since been approached in size or equipment. With it I safely lifted from the earth, including its own weight, sixteen tons, so that I was thoroughly convinced that I could safely convey across the Atlantic all the materials I required for comfort and safety. Not only was this balloon fitted to carry ample instruments, provisions for the crew, and all the implements, etc., required for observation and the manipulation of the balloon, but also a full-rigged life-boat schooner with air-tight compartments, built of light steel plates.

Chambers' and other encyclopedias state that this balloon would lift 22½ tons. In order that the reader may not misunderstand the apparent discrepancies between their statements and mine given above, permit me to explain that had the balloon been filled with pure hydrogen gas, it would have lifted 22½ tons, but on this occasion I had to use the ordinary coal gas, which, being heavier, permitted me to lift only 16 tons.

Professor Henry, however, was so adverse to my running any risk in making the trip over and across the Atlantic, that he suggested before doing so I should thoroughly test the existence of this current over a long land distance. He advised me to go west with my bal-

loon to make an ascent when the earth currents were blowing strongly to the west. When reaching the upper currents, if I sailed east across the continent, the existence of this eastward current would be sufficiently demonstrated to justify his urging the government to aid me in continuing the experiments with a view to the organization of the Weather Bureau—an object to which I had devoted my attention for many years.

Acceding to Professor Henry's request, I left my large balloon, and, taking my smaller experimental balloon, went to Cincinnati, and for about a month waited for conditions to be exactly as I desired before making the ascent. The newspapers took a great deal of interest in the project, some of them speaking in the most favorable terms of the work. At last the conditions were highly favorable for the experiment, the surface currents moving rapidly westward, and, accordingly, after learning by telegraph that the same conditions existed as far east as Washington, I made the ascent at about 3:30 o'clock on the morning of April 20, 1861. It was fully midnight before I was satisfied as to the existence of these westward-blowing earth currents extending from the Atlantic to Cincinnati, and then, having arranged with the superintendent of the city gas-works for the inflation of the balloon, I proceeded at once to direct that important and necessary work.

My readers must here understand that gas, exactly the same as atmosphere, absorbs and holds in suspension in warm weather, more moisture than it does when it is cold, so that, the day having been warm and

murky, the gas with which the balloon was inflated on this occasion held its full proportion of moisture in suspension.

In ascending, I started rapidly toward the west, as the surface currents from the east were quite strong. When I reached an altitude of 7000 feet I struck the eastward-flowing current, and here very rapidly the thermometer went down to zero. This sudden cold congealed the moisture, held in the gas, and formed a fine, glassy, bead-like hail, which in the absolute stillness I could distinctly hear falling upon the silk and rolling down the neck of the balloon. Being night-time it was impossible for me to see it, but under similar circumstances in the daytime, I have seen a miniature snowstorm going on inside the balloon when I have left a warm for a cold current of air. It was not a soft snow this time, but, no doubt owing to the rapid change into so great a difference of temperature, it was a hard, bead-like hail. The neck or lower end of the balloon was opened to let the expanding gas escape, and a bushel or more of this fine hail was discharged.

This caused the balloon to ascend still higher, until, by looking toward a star over the top of the mercury column in the barometer, through a slot I had arranged for that purpose, and feeling the raised figures—for it was dark and I had made no arrangements for lighting—I found that the balloon was at an elevation of 14,000 feet.

This altitude it retained until sunrise, when the heat of the sun expanded the gas still further, and it rose to an altitude of 18,000 feet.

And such a sunrise!

The horizon appeared always on a level so that the earth resembled a great hollow bowl, with the exception of the Blue Ridge mountains, which, owing to their great distance, fully 200 miles, resembled a solitary peak arising from the ocean.

As sunrise approached, the streaks of light rapidly running around the horizon resembled bands of molten gold, and when the sun itself appeared, I was never more astonished and surprised. It was entirely different from our every-day luminary. There was a total absence of its usual dazzling appearance. It resembled a disk of burnished copper, as such a disk would appear when not in the bright rays of any powerful light. The singular appearance was retained during the time of the entire voyage, so long as I remained at an elevation of from 16,000 to 18,000 feet. This fact proved to me that the dazzling appearance of our great luminary is caused by our atmosphere and the elements it contains, or holds in suspensicn, within three or four miles of the earth.

The sky, too, was inexpressibly beautiful, even during the daytime, resembling a rich, dark-blue velvet, and the sun, moon, and some cf the stars were all visible at the same time.

To return to the point of departure. Mr. Potter, proprietor of the "Cincinnati Commercial," and Murat Halstead, the editor, arranged to be with me at the time I decided to make the ascent. They brought down a number of delicacies of all kinds for me to take along, and Mr. Halstead thoughtfully provided me with a

large jug of hot coffee, which he wrapped up in a number of blankets in order to keep it hot, which it did throughout the entire journey. He also brought me 200 copies of the "Cincinnati Commercial" announcing the preparations that had been made for this trip, that the balloon was now being inflated, and that, "shortly after going to press Professor Lowe will have left the earth for the purpose of making his long anticipated aërial eastern voyage."

Some of the newspapers amusingly stated, after I had ascended, that the balloon which had gone up for the purpose of demonstrating the existence of an upper air current which invariably flowed eastward, when last seen was rapidly sailing west, but quite a number of spectators, even after the balloon was enveloped in darkness, discovered its course by the occasional eclipse of a star, which showed them that the line of movement had changed to the east, and later in the morning, at daylight, telegraphic despatches were sent all over the country from Falmouth to Lexington, Ky., saying that a large balloon had been seen rapidly moving eastward. All who saw the despatches and knew of my discovery were convinced of the correctness of my former deductions.

The average height at which I sailed was about 16,000 feet, but in crossing over the Alleghanies I discovered that air currents bound and rebound exactly as the currents of water do, when flowing down a stream against large boulders and ledges. The air was flowing rapidly eastward, and as it struck the crests of the Alleghanies it caused an extra upward movement

of the balloon. In a few moments I ascended to a height of 22,000 feet, probably 6,000 feet higher than the balloon could have gone by its own lifting power, and when it made the curve on the other side of the range, I descended so rapidly that the fall was about a mile in one minute. Though racing through space with such extreme rapidity, everything around me was perfectly quiet and still—so still that I could have carried a lighted candle without any protection, and I left loose sheets of paper about without any fear of their being disturbed. The reason for this may not be quite clear to all my readers. I was floating *with* as well as *in*, the undisturbed atmosphere, consequently there was not the slightest sense of motion whatever. The altimeter, my instrument for measuring latitude and longitude, and thus determining the rate at which I was traveling, showed such a rapid movement of the balloon to the east that I doubted its accuracy, until I glanced down over a rope, hanging for one hundred feet below the car, and there noticed the short space of time it required to cross large farms, fields, woods, etc. The velocity was so amazing that I no longer doubted the accuracy of the registrations of my altimeter, but not feeling entirely sure of the state I was then over, and seeing with my glass some plowmen in a field many miles in advance of me—pretty well up on the west slope of the Alleghanies—I descended toward the earth to make a flying inquiry as to the location. When within hailing distance I descended into a neutral current, and standing nearly stationary shouted to the men at the plow, "What state is this?" They looked every

direction except upward, without replying. I shouted again, and as the sound probably seemed to come from the woods, and while trying to ascertain the direction from which the voice came, they shouted: "Virginia." At that, with a "thank you," I poured out quite a quantity of sand from the ballast bag, and as this came pattering down on the earth near the men, they glanced upward, only to take to their heels to woods near-by in affright, while their aërial visitor was rapidly ascending into the eastward current again.

Before reaching the Alleghanies, owing to the flow of a deep and rapid current of air between that range and the Blue Ridge, my balloon was drawn slightly southward, out of the direct eastern path, and I finally landed in South Carolina, a short distance from the line of North Carolina.

When I first descended from the higher atmosphere I found myself near the coast, and decided I had better return a little inland and find a better landing-place than the rice fields I saw coming into view. When I had gone as far as I thought was necessary I pulled open the valve and rapidly descended, to find myself quickly surrounded by several planters and negroes. The latter were ready to aid me, but the former ordered them away, and commanded me also to leave in short order. I asked a few questions as to my location of one young white fellow, who seemed disposed to be friendly, and, as soon as I had gained what information I wanted, I concluded that it would be better for me to find a more congenial landing-place, where I should be nearer to a railway. The planters kept warning me

that they would not be responsible for the consequences if I persisted in staying, so, lifting up a bag of ballast, I tipped it over the edge of the car, and, at once, ascended rapidly. Fearing some one might shoot and injure the balloon, as they all had muskets, I used a large bag of ballast so that when I did ascend I should go up rapidly. I was much amused as the balloon shot up from the earth to hear the young fellow call up to me: "Hello, mister! I reckon you 've dropped your baggage!"

I left the "baggage" for them to investigate if they desired to do so, and was soon floating away westward for a short distance, until, when I had reached the proper height, the balloon again moved eastward, giving me another demonstration of the existence of the eastward-flowing upward current. This time I heard firing all along until I again landed. I was about two miles up in the air, but the people below thought I was only a short distance from them, and, never having seen such an object before, kept up a-firing, thinking to "bring such strange quarry down."

When I had gone, as I thought, far enough, I again essayed to land. I was just above Pea Ridge, doubtless so named because it appears as if nothing will grow on it except peas and pitch pine. When I approached the earth the feathered tribe was the first to notice my appearance, and the air being the realm that they alone are supposed to navigate, they took my balloon for some great hawk or other predaceous bird, and imagining themselves in great and dire danger, immediately flew to shelter, making a great cackling and screeching as

they went. This sent consternation into the hearts of the negroes and whites, who, by this time, were watching my movements with increasing interest, so that when I finally landed in the midst of the cabins occupied by whites and negroes, they had all fled, and it was some time before any one would approach to aid me in anchoring the balloon.

What a commotion my coming caused! Not a soul was in sight. They had all taken shelter in the various cabins, from many of which I could hear groans, praying and other symptoms of distress and alarm.

After the anchor had firmly taken hold in a heavy rail fence and the balloon was quiet, I called to the people inside the cabins.

Presently doors began to be furtively opened, and from the rear of the cabins as well as the doors, heads peeped out.

I asked some one to come and aid me steady the car, but no one, either white or black, responded, until at last a young white woman, possibly eighteen or twenty years of age, standing fully six feet high and well proportioned, came forward with a pleasant manner and a smile, and asked what she could do.

I explained to her that I wanted the car steadied until I could discharge sufficient gas from the balloon to allow the car to remain firmly on the ground. Immediately she took hold, then came other whites and a number of negroes and held on likewise, and I was soon the recipient of more attention than I desired.

This white woman was the only brave person in the

whole crowd, and I shall have occasion to refer to her later on.

I could see the people, while the balloon was descending, congregating from all directions. They had followed me as closely as they could, some on foot and some on horseback, most of them armed with shotguns; and every now and then a new arrival would appear on the scene. It was amusing to see each man, as he approached, sneakingly deposit his gun under the fence, as if ashamed to be seen with arms under such circumstances.

As I had decided to make this my landing, I opened wide the balloon valve to allow all the gas to escape, and many of those present never having smelled this element before, held their nasal organs in intense disgust at the odor, and ran to escape what they considered its vile and noxious influence. I motioned to them to keep to windward so that they would not be annoyed, but all my movements were viewed with considerable suspicion, and as the balloon grew less and less the onlookers became more and more bold and aggressive, in both remarks and gestures.

Many of them still thought I was an inhabitant of some ethereal or infernal region, who had floated to this earth to do damage and injury to its inhabitants, and I thought to pacify them and convince them I was human, exactly as themselves, by showing them I had to live on the substantial things of earth just as they did, so I took from the basket quite a variety of cakes, crackers, bread and butter, rolls, cold meats, chicken, etc., and the other delicacies presented to me when leav-

ing Cincinnati, eating some myself and passing the rest around. I also passed out several india-rubber bottles of water which had frozen solid, and, to let them realize how cold it was in the upper regions of the atmosphere where I had been, I cut one of them open and took out a large mould of ice, shaped exactly the same as the bottle.

This was the worst thing I could have done, for immediately one man asked how could anyone but a devil put so large a piece of ice through so small a place as the nozzle. Others began to call attention to the difference in the cakes. Those portions which had been exposed were frozen, the others were not. Some of the apples and oranges which had been under the blankets were perfectly good, others frozen as hard as rocks.

The two-gallon jug of Murat Halstead's coffee wrapped up in a dozen thicknesses of blanket, was still as hot as one would care to drink it, and all these astonishing, and to them contradictory things, instead of impressing them with the fact that I was but an ordinary human being, gave them more cause for alarm than ever, until, finally, all the gas by this time having been discharged from the balloon, and the giant lying limp and harmless on the ground, one old man—of dissipated countenance—suggested that a Yankee who was capable of doing all these things was too dangerous a man to run loose, therefore he moved that he be "shot on the spot where he had dropped from the skies." Quite a number approved of this motion and thought it would be "serving him right," others,

more conservative, thought an investigation would be better.

The friendly young woman before referred to, fearing I might be alarmed by these "shooters on the spot," again approached me and volunteered the information that I need have no fear. Said she: "Most of them are cowards; all the brave men of the neighborhood have gone to war."

While they were discussing me, pro and con, I began unloading the instruments from the car. Many of them were very elaborate and curious—the alimeter, for determining the latitude and longitude without a horizon; the long, mercurial barometer, especially constructed for my use and before described, for determining altitudes; the telescopes and hydrometers, etc.

As the crowd saw these, their alarm increased, for they knew at sight they were all fearful instruments of destruction of one kind or another, and what gave emphasis to this fear was that I finally displayed a large Colt's revolver, which I had had the precaution to take along with me, thinking I might possibly have occasion to use it.

I then and there let the aggressive portion of my surrounders understand that the first man to make any hostile advances toward me would go into eternity far quicker than I had descended into their locality, but that I was willing to further any investigations they desired to make. I suggested that they appoint a party to go with me to the nearest county seat, which I afterward learned was about ten miles away.

After a good deal of parley with the different squads,

my compromise was accepted, so I packed up the balloon and all the car paraphernalia, and then placing the same in the car, I joined the conservative portion of the party and went to one of their cabins to await the getting ready of the wagon which was to take me to Unionville, keeping my eyes alertly upon the belligerents, however, in which I was zealously aided by the friendly young woman, whom I afterward found lived in the cabin where we were going, and was the daughter of one of the chief men in the conservative element.

The cabin to which I was escorted was a large one-room log house with an open fireplace of generous dimensions. In each corner were two little negroes, playing with their feet in the warm ashes. I could not help the reflection that upon the future growth of each of those black youngsters depended from $600 to $1,000 to their owner. Some one announced that in a few minutes an early supper would be ready. When about three o'clock, the man announced that they must begin to eat at once, as it was necessary to make an early start in order to get over the rough roads to the county seat before dark. Considerable time had already been lost in getting the mule team ready. We were asked to sit up to the rough table on our three-legged stools, and, as we sat, the ashes were removed in the great fireplace, and a large cast-iron Dutch oven brought forth. On opening it, about two dozen good-sized "corn dodgers," about the shape and size of a goose egg, were revealed, cooked to a rich, dark golden brown. I thought to myself how delicious these would taste when the butter was put on the table to join them.

But, alas! I was doomed to disappointment. There was no butter! Such a thing it seemed was unknown among the pines, and as for bacon, I was informed, with many apologies, and in a most mournful tone, that they were not able to obtain it, as what little there was in the country had been taken for the army, and—with an added tone of indignation—that "Abe Lin-korn's" gun-boats were preventing more from coming in. Coffee also was an almost unknown luxury, the left-over crusts of the "corn dodgers" serving in its stead.

But to make up for loss of butter, bacon and coffee, they brought out a jug which had been set aside as a reserve for special occasions, containing Louisiana molasses. Even this was nearly all gone. As the entire capacity of the railways was being employed in conveying troops, it was difficult and expensive to get goods of any kind.

A younger brother of the girl who had aided me, in his desire to make me think well of the locality, said: "You ought to be here in summertime when we have blackberries and molasses, then these dodgers taste good!"

I still had a satchel full of sweet and dainty delicacies, so desiring to return in some measure the cordial, though rough, hospitality of the friendly woman, and to further propitiate those who were inclined to be kind to me, I distributed its contents freely. I ate of their corn dodgers and praised the former highly, to the evident delight of my hostess, who had made them, and then I had to listen to the praises bestowed upon my

cake—the best that the ladies of Cincinnati knew how to make.

The repast being over, a six-mule team and wagon were driven up, into which were placed the balloon, the car and all its belongings. My whole outfit only weighed a little over 200 lbs., so I asked them why they had brought so many mules? The driver replied that when he started for them he thought he had to load in that great, monstrous balloon, so he put on two extra animals, and that he never drove over those rough roads with one of these heavy wagons with less than four. The wagon was a heavy, lumbering affair, used for hauling rosin.

Everything being in readiness, off we started.

The scene was a picture worthy a master brush. Let me endeavor rapidly to portray it for you.

When I so hastily left Cincinnati, I was clothed in my usual costume of black, wearing a tall silk hat, little thinking how soon my dress would be in such marked contrast. The people among whom I had fallen had long hair and beards, mostly sandy-red in color, reaching to their short rotund stomachs, wore slouch hats, and blue jean clothes. Mounted on shaggy horses, each man with a shot-gun over his shoulder, three on each side of the heavy, lumbering wagon, drawn by six mules, acted as a sort of military guard and escort to myself, who, in black Prince Albert costume and silk hat, sat in regal state on the basket in the wagon. Around us was a motley crowd composed of the belligerents, the still scared negroes who scarcely knew what to make out of the whole proceeding, the

half-clad youngsters of both colors and sexes standing open-mouthed and open-eyed gazing upon a scene they had never witnessed before and most probably never would again.

By this time a crowd from the surrounding region had assembled, drawn hither by the strange spectacle of the floating and descending balloon; so, under these circumstances, I bid farewell to Pea Ridge. It was an absolute farewell, for I have never seen it, nor heard from the people I met there, from that day to this.

After a long, dusty, jolty ride, with scarcely any conversation, and with but little to break the monotony, except the clatter of the mules' hoofs, the clanking of the chains, the jolting of the wagon, and an occasional "cat-nap," we arrived at Unionville, about ten o'clock that night.

As I had not closed my eyes in sleep for over thirty-eight hours, I could not refrain from "napping" as we rode along, and I would sleep until rudely awakened by a little rougher jolt than usual. As soon as the wagon settled down to an easy motion I would drop off to sleep again. But the stopping of the team before the old jail at Unionville aroused me to full consciousness, as it was the first full stop we had made.

A portion of my "guard" aroused the jailer, and conversed with him in a low tone. The substance of the talk I could only surmise from the reply of the jail-keeper, who said, in a louder tone, that if their description of the man they had was correct it would be of no use to place him in that jail. They had better take me

to the hotel and keep me under guard until the next morning.

This suggestion seemed to meet with their full approval, for they drove on, and in a few minutes hauled up in front of a long, two-story, roughly-built house with a porch extending its entire length, on which the country people when in town lounged away their spare time between drinks.

The landlord was aroused, and a similar whispered consultation took place between him and a portion of the guard, as at the jail. He was unable to understand what they were talking about, and asked to see the man who was giving them so much trouble. He lit up the main reception room, and then I was escorted in for him to see and determine the dangerousness of my character.

I had no sooner entered the room than he quickly came forward like an old acquaintance, with extended hand and, calling me by name, said he remembered me well, and that he had made a "cable trip" with me in my balloon at Charleston, S. C., the year before, at which place I was then making meteorological experiments and observations. His name, I soon learned, was Fant, and he had been a town official, and was a highly esteemed and respected citizen of the place.

It was amusing to see the expression on the countenances of my guards as this brief interchange of compliments took place. They were literally dumfounded, and stood without a word to say, and with an expression of blank amazement and astonishment. Then one of them in a slow and deliberate, though evidently

confused manner, began to make apologies, in which several of the others joined. I replied that they had no occasion to offer me any apologies; they had rendered me real service, such as I would have been willing to pay well for had they not volunteered to take me in charge, and that I could not think of their leaving the house without partaking of the best refreshment the house afforded. I then asked Mr. Fant to arouse his servants and get up as good a supper as possible, for my own appetite was sharp enough even at that late hour.

While this was being done we all sat down, and in a friendly way talked freely about the events of the day. The guests of the hotel, hearing the unusual noise, were interested enough to inquire what was going on, and immediately arose, dressed, and joined the party; and those who were sufficiently well informed to appreciate the distance I had traveled in the balloon expressed great wonder and surprise at my having made so long a journey in so short a time.

A hotel keeper in that part of the country is generally a man of influence and importance, so that when Mr. Fant informed my guard from the rural district that their services would no longer be needed in that capacity, as he would vouch for me, his decision was at once accepted without demur. He explained that he knew the history of my scientific researches and the object of my balloon investigations; that he had met me in a lodge at Charleston, S. C., and that I was "all right."

When supper was over and all were suitably re-

freshed, I gave to my guard the amount of cash I should have had to pay for their services had I engaged them, and they left me with many regrets and apologies if they had been a source of annoyance to me. I assured them of my satisfaction with their conduct, when they turned their team homeward, and I never saw or heard from them again.

Being exceedingly fatigued with my labors in making preparations for the voyage, and owing to loss of sleep, making continual observations during the journey, the excitement consequent upon my landings, and the ride in the mule-wagon to this point, I immediately retired and was no sooner in bed than I fell into a deep and refreshing sleep.

But it seemed to me only a few moments after retiring when I was aroused by a knock at the door, and on opening my eyes I saw the sunlight shining in the room and was told that it was seven o'clock.

I informed the landlord, Mr. Fant, that I was so very tired that I did not care to arise before noon. He replied that it was very desirable that I do so at once, as a large crowd of people had gathered about his house, waiting to see me, and he thought a look at me would satisfy them so that they would go away. He was afraid of so large a crowd remaining, especially as many ugly remarks were being made about the Yankees, the hostilities against the North having created a strong sentiment against all Northern people.

I arose at once and a glance out of the window demonstrated that the landlord's statement was not exaggerated. I dressed as quickly as possible, and, in look-

ing into the mirror to adjust my cravat, I found that my face was very red and swollen. When I was in the balloon, and while the thermometer stood from 15 to 20 degrees below the freezing point, the pure atmosphere I was drifting in, having no moisture or floating particles to modify the sun's rays, and, as the curious appearance of the great orb of day caused me to observe it intently, I felt a pricking sensation on my face as if a thousand or more needle points had been thrust into my skin. I attributed this sensation at the time to some peculiar electric effect consequent upon the high altitude, but afterward concluded that it was the unintercepted rays of the sun. It had certainly caused the worst sunburn I have ever experienced, either before or since. But as my face was unburdened with a superabundance of flesh, it did not appear to others as bad as it felt to myself, so I made the best of it and soon found my way down-stairs.

Here, in the parlor, a number of gentlemen were waiting to see me, among others the sheriff of the county, to whom I was first introduced, then to the editor of the Unionville paper, afterward to Mr. Thomson, a member of the South Carolina legislature, and other prominent citizens. Mr. Fant and the sheriff proposed that we take a ride just as though I was an ordinary visitor to whom they wished to show the town. This would give the people an opportunity to see me and let them know I was not a person to be feared. They thought we had better not wait for breakfast, as they would like the crowd to disperse as soon as possible. Many of these people were from the sur-

rounding country. They had followed the balloon in its flight, traced its descent to Pea Ridge, there learned of my conveyance to Unionville, and, determined to see all there was to be seen and find out more about the strange object they had seen floating in the air, had followed the wagon and were now determined upon seeing me. I did n't wonder at it when I learned that some of them had come sixty, eighty and even a hundred miles in their search for me

The conveyance being in readiness, the editor of the paper and Mr. Fant took the rear seat, with the sheriff and myself in front, the sheriff driving, and as he took the lines we bowed to the people as if they were giving us an ovation. For three hours we drove around the city, and then, returning to the hotel, found that fully two-thirds of the crowd had disappeared, the others still remaining to learn more of the wonder they had heard so much about—the balloon, and of that mysterious stranger whose marvelous descent from the heavens had so startled them and thoroughly aroused their curiosity.

These people were somewhat satisfied by my friends, and then we took breakfast, after which a couple of lawyers with the town officials having stepped in, they, the editor and Mr. Thomson asked a great many questions of me as to the purport of my journey, the distance traveled, the time occupied, etc.

My answers were not disputed, yet I could see while making my statement there was an unexpressed feeling of doubt, which was confirmed by the perfect silence which reigned when I had concluded.

Finally Mr. Thomson asked me if I could give them any tangible evidence that I had left Cincinnati the same morning that I landed at Pea Ridge, as it seemed to them all incredible that a trip of that distance could have been made in so short a time. I stated that I would pay the expenses of a telegram to Cincinnati and return if they desired or, what would perhaps answer their purpose just as well, was a sight of the "Cincinnati Commercials" which I had with me, that I had received wet from the press that morning just before my departure. The editor immediately exclaimed: "That will be proof sufficient if you show us that paper."

I said I had quite a number of the papers in one of my sandbags, packed away in the folds of the balloon. I had hidden them because the "Commercial" was considered in the South an abolition paper, and the penalty in South Carolina for distributing abolition documents being death I had thought it best not to show them.

At this suggestion they were all delighted, for it would not only prove the truth of the—to them—wonderful journey, but would also give them the latest news from the North, which they were all anxious to learn. They assisted me in getting out the package, and, as I drew out the papers still damp from the press they read the account already spoken of, and unanimously declared that was proof sufficient and that nothing further was necessary. From that time on I was an increased object of their wonder and admiration, and they all desired me to visit them at their

homes. One of the most cordial and pressing invitations came from Mr. Thomson that I would take dinner with him, so I accepted it and accompanied him to his home. It was the finest residence in the neighborhood, and his family one of the most pleasing and intelligent in the state. They informed me that their son had just raised a regiment and was on his way to Manassas Junction.

Mrs. Thomson took great pride in her garden, and invited me to see it with her. She showed me the lettuce, asparagus, radishes and other garden delicacies which she was growing for her son, which she explained she would send him, as well as eggs, chickens, fresh butter, etc., until the Southern army reached Washington. Then as it marched farther north, she had no doubt he would be able to capture all he would require. Poor lady! Like many other mothers she had great confidence—unfounded in this, as in many other cases—in her son's ability to go wherever he pleased.

There being no train out of Unionville on Sunday, I remained there the entire day, visiting the newspaper offices and other places. I also obtained a certificate of the hour and place of my landing, signed by several of the most prominent citizens, including all the gentlemen I have before named.

Next day I took the train for the North to enter into another series of most unexpected and exciting adventures.

With the balloon and instruments, I started for Washington by way of Columbia, S. C. The train had many refugees on board, together with Southern

troops and officers going north to join the army then forming in Virginia, but little of interest to me occurred until we entered the depot at Columbia.

I was surprised to see the great crowd assembled in and about the depot, but thought nothing of it, supposing that the attraction was the passing troops; so, picking up my barometer, which was in a long leathern case, I slung it across my back, and with both hands filled with instruments in cases, started up the depot to the baggage car, to have my balloon paraphernalia transferred to the next train, as in those days each railroad ran its own section, and each traveler was required to look after the transfer of his own baggage at the points of junction.

I soon heard exclamations such as: "There he goes!" "That 's the fellow with that gun on his back, and infernal machines in his hands!"

My long strides and hurried steps—for I had only a brief time in which to change cars and get my baggage transferred—were not sufficient to enable me to keep ahead of the crowd that was following me, and before I reached the baggage car I was stopped by a long black-bearded fellow, who held a revolver in his hand, tapping me on the shoulder, and informing me I was his prisoner. I immediately took in the situation, and asked him where he wished me to go. He gruffly replied: "To jail!" The crowd, by this time was rapidly growing, and cries of "Tar and feather the d—— Yankee," and similar expressions were heard, while some kindly-disposed spirits suggested that, "That 's too good for him; better hang him!"

As the crowd was surrounding us, and was disposed to be ugly, seeing a carriage close by I suggested we take it and ride to our destination. He agreed, if I would pay for it, so I invited him to take a ride with me. We jumped into the vehicle and were driven to the jail, the crowd running as fast as the carriage, evincing the deepest interest in our movements.

The people had evidently been informed from Unionville and other places of my strange and sudden appearance in the South, and my arrest had been ordered by the military and civil authorities.

While riding to the jail, the sheriff was very sullen and not at all complimentary in his remarks. He stated that I had a great deal of assurance to dare to travel in the South at those times, and that "A d—— Yankee was known by his assurance at any time."

We soon arrived at the jail, and I heard the music of the big rusty key turning in the lock, opening the cell I was to occupy. It was of generous size and already had one occupant, as I could see at a glance. Many other of the cells were also filled, but all was silent as the grave.

But I was not to be incarcerated for long, as my case was the uppermost one in the minds of the officials. In less than fifteen minutes the mayor and councilmen appeared and I was taken into the jailer's large room for examination.

I stated to the mayor that I had gone through a satisfactory examination in Unionville, and that I was well-known by many people in Charleston, who were familiar with the objects of my aëronautic investiga-

tions, and I had no doubt there were gentlemen in Columbia who were familiar with my profession and the object of my work, and drawing from my pocket the certificate given me by the citizens of Unionville, I asked his consideration of it, together with the notice of my ascension in the "Cincinnati Commercial."

I was then asked by some one in the party if I was acquainted with the officers of the South Carolina College; I replied that I was not, but that I had often heard Professor Joseph Henry speak of the president of the college, and that as Professor Henry was my friend and co-worker, I presumed that if they would send for the president of their college they would be able to gain some information of me and my work from him. They sent at once for the president and faculty also, and soon we had quite a meeting of the educational and literary élite of South Carolina. The president and others of the faculty said they had read of my experiments with much interest, in this department of scientific work, and they verified my statements as to my association with Professor Henry.

Upon hearing this and other statements the whole party soon became more enthusiastic in my favor than the sheriff at first had been against me, and it was amusing to see the change come over him, both in countenance, expression and temper, as he sat and listened to the testimony which exonerated me of any dangerous intent. They then took a vote as to giving me my liberty, and it was unanimous in my favor, whereupon the mayor volunteered to give me what he called a

passport through the Confederate States of North America, which read as follows:

Columbia, S. C., April 22, 1861.

This is to Certify, That Prof. T. S. C. Lowe, now accidentally in our midst, is a gentleman of integrity and high scientific attainments, and I bespeak for him the courtesies of all with whom he may come in contact, and trust that this letter, to which I have affixed the seal of the City of Columbia, S. C., will answer as a passport for him through the Confederate States of North America.

(Signed) W. H. BOATRIGHT, Mayor.

The crowd about the jail was now many times greater than it had been at Unionville, and the mayor feared trouble from the people who did not understand the situation. He suggested, therefore, that we take a walk through the streets of the city and visit the college and other interesting portions of the town. Taking his arm, we left the jail—to meet another astonished and disappointed crowd. The mayor and the officials of the college being exceedingly popular, the people made way, and no attempts were made to crowd upon us, as was the case when we were on our way from the jail to the station. It was soon noised about that my presence was perfectly satisfactory to the authorities, and the crowd dispersed.

We went to the hotel, as I had invited the mayor and the faculty to dinner with me. While we were dining, I took particular note of what was going on, as the many uniformed officers occupied tables near-by. My

companions were quite interested as well as interesting, so we continued our conversation for a little while, they accompanying me to my rooms, supposing that I should have no further annoyances.

I learned that I could not proceed farther north, the train I was on in the morning being the only one that would reach Washington, as the blockade of trains to the North had now been made complete at Manassas Junction. The only way to get back to Cincinnati, therefore, was to return by way of Louisville, Ky., and that train would not leave until the middle of the afternoon.

I then started on my four days' journey back to Cincinnati, the same journey I had taken, though in an opposite direction, in the balloon, in the brief space of less than nine hours; and these four days, while not so exciting as the one just past, were equally full of interest.

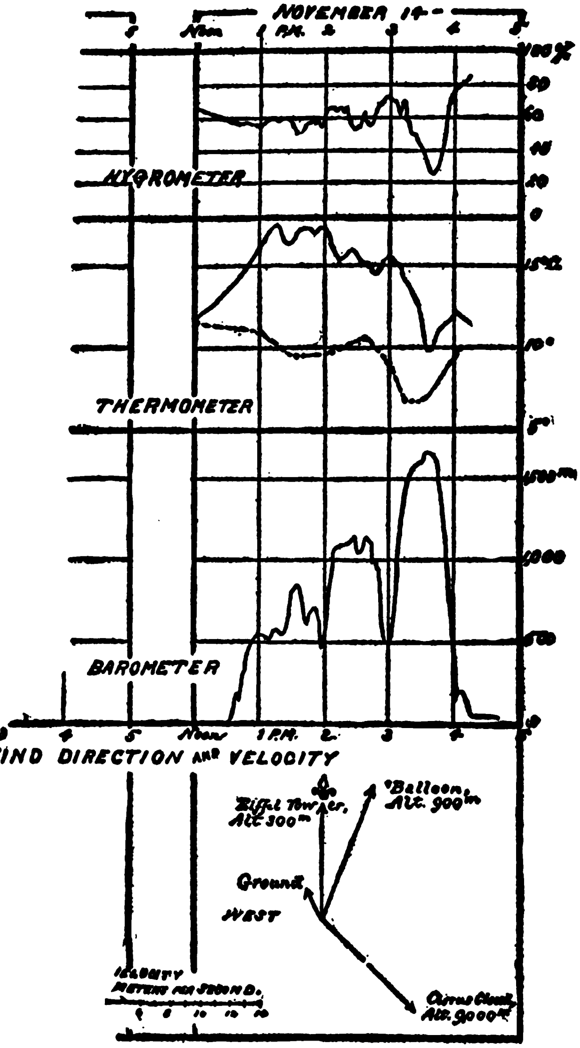
XI

A FLIGHT OVER PARIS

By William J. Hammer
Consulting Electrical Engineer

IN the year 1889, after an arduous experience at the Paris Exposition, where I had the honor to represent the interests of Mr. Thomas A. Edison, I decided to carry out a long-cherished plan of making a balloon ascension; and having secured a large silk balloon of 27,000 cubic feet of gas capacity, I invited Dr. A. Lawrence Rotch, Director of the Blue Hill Observatory, Boston, and Dr. Rufus G. Wells, the well-known aëronaut of St. Louis, to accompany me. On November 14, 1889, we made an ascension from the La Villette Gas-works in Paris, and this trip I consider not only as the most interesting experience of my life, but worthy of record, by reason of the various scientific observations made and experiments carried out during the three and one-half hours we were in the air.

The balloon was designed to carry five people, and I had made a contract for a supply of hydrogen gas, but we were forced to content ourselves with ordinary illuminating gas, and by reason of a large amount of apparatus which we desired to take with us three



Meteorological record of balloon ascent at Paris, Nov. 14, 1889

people were all that we could satisfactorily carry. As we were on the point of starting from the gas-works about noon, some French military officers appeared on the scene. They had learned of our proposed ascent, and we had considerable difficulty in taking our departure, and were only allowed to do so by proving that we were not spies, and giving our promise that we would make no photographs of the fortifications about the city.

The ascension was particularly interesting from the fact that it was one of the few ascents which had been made up to that time, in which recording meteorological instruments were employed, these being the barograph, thermograph, and hygrograph of Richard Fréres, designed to record continuously barometric pressure, temperature and humidity of the atmosphere. These instruments were controlled by direct readings of aneroid barometer, thermometer and hygrometer.

On leaving the earth, the temperature was 54.5° Fahr., and the relative humidity 68 per cent. The normal decrease in temperature with elevation is 1 degree Fahr. for each 300 feet of ascent, but in this case it was much slower.

The balloon was in the air three hours and a half and traveled at an average of 20 miles an hour. The highest altitude attained was a little more than a mile and the average height about three quarters of a mile.

The accompanying diagram is a copy of the record sheets of the recording instruments, and was prepared with certain of the meteorological data by Dr. Rotch for his lectures before the Lowell Institute of Boston

in 1891. The lower traces of the diagram are those of the barograph, which show the height in meters, assuming the pressure and temperature decrease to be constant. The middle traces are from the thermograph, showing the variations in temperature. The dotted lines below are made up from readings of a sling thermometer, both being plotted on a centigrade scale. A sling thermometer is simply an ordinary thermometer tied to a string and swung in a circle, and such an observation, even though made in the sun, gives a very good approximation to the shade temperature, and avoids all trouble of the free circulation of the air around the thermometer. The thermograph was shielded as much as possible from the sun, which was not easy, as the balloon was constantly turning on its axis and exposing another side to the sun, so that the gas-bag itself became heated. The divergence of the two curves shows the undue heating of the thermograph causing it to record 8° Cen., or over 14° Fahr., too high. The upper tracings are the relative humidity in per cent. of saturation obtained from the air hygrograph, whose indications were controlled by means of a dew point apparatus. In general, at the earth's surface, a temperature and relative humidity are the reverse of one another; that is to say, that when one rises, the other falls, and *vice versa,* but in ascending to high altitude, both the absolute humidity and the temperature are low. This was noted at the height of about one mile when the temperature fell to 44 degrees Fahr., and the relative humidity to 25 per cent. For the reason which causes the lack of ven-

tilation to the thermometer a free balloon is one of the best of anemometers, since it has the motion of the air in which it floats, so that by noting the time of starting and landing and the places passed over, a good knowledge of the wind's direction and velocity is obtained.

In the voyage of November 14, the height was very variable, averaging 900 meters or six tenths of a mile. The distance traveled in a north-northeast direction being 71 miles in three and a half hours, giving a speed of 20 miles an hour. The wind, meanwhile, at the level of the Eiffel Tower blew with an average velocity of 16 miles an hour from the south; in both cases the upper winds veered with respect to the lower, that is, they were deflected toward the right hand, and this was the case from the earth's surface up, as shown by records of the meteorological stations near Paris, where the wind direction differed from that on the Tower. These facts are recorded in the lower portion of the diagram where the arrows fly with the wind, and in length are proportional with its velocity expressed in meters per second. This diagram shows that change in direction which would be expected from an inspection of the synoptic weather maps of Europe on these days.

In addition to these meteorological observations, the balloon was equipped with several cameras for taking photographs of cloud effects, the shadow of the balloon on the earth and on the clouds, and of various sections of the country over which we passed. During the progress of our journey, the writer dropped a dozen parachutes to which were attached sealed boxes

containing phonograph cylinders, illustrating a method devised by him, by means of which an officer making observation from a military balloon could dictate such observations to a small phonograph attached to his side, the cylinder of which, if captured by the enemy, would not possess any cypher or key, as it would be necessary to place the cylinder upon a specially designed phonograph in order to hear the record which would then be given in the voice of the officer dictating the despatch. I found that by properly weighting these parachutes, the cylinder could be dropped with perfect accuracy within certain zones, and with perfect safety, and by attaching a small storage or dry battery and an incandescent lamp, or if desired a "bengal" light, they could be utilized at night. The sealed boxes contained directions for forwarding them to my hotel in Paris, the necessary postage, and cautions as to handling. One of these cylinders was returned to me from a distance of 65 miles from Paris, and others from intermediate points. The balloon was equipped with a speaking trumpet fifteen feet in length, which I had borrowed from the Edison exhibit, and by means of this we were able, by placing it alternately to the mouth and to the ear, to carry on a conversation and make inquiries as to our location in passing over the ground at high altitudes. I also found that I could check roughly the barometric pressure records of our height by the reflection of sound from the earth, taking the time with a stop-watch.

On one occasion in passing over a small town the writer seized the speaking trumpet and shouted lustily

to the excited populace below, *"Vive France! Vive Carnot!"* when an irate Frenchman with an apparent antipathy for the then existing régime of President Carnot, and a predilection for the "man on horseback" leaned far out of a farm-house window, and shaking his fist vigorously at us shouted, *"Mais non! mais non! Vive Boulanger!"*

I remember one particularly exciting incident occurring during the trip. Upon leaving my hotel in the morning I had, for almost the first time in my life, carried a revolver in my hip pocket and at a time when the balloon was nearly stationary, a height of a mile, I drew the revolver from my pocket; when the experienced eye of Dr. Wells catching sight of it and fearing an explosion of the gas, which constantly trickles from the open neck of the balloon, threw up his hands and shouted, "For Heaven's sake, don't fire that thing off!"

I replied, "I do not intend to unless it is absolutely necessary."

"What do you mean?" he said, sharply.

"Well," I replied, "supposing we were descending rapidly and had exhausted our ballast, and were rapidly approaching buildings or a cliff; and supposing the valve-cord had broken and we could not let the gas out quickly enough to permit our landing before we struck the obstacle" (as there was no rip-cord such as is now universally used to tear open the balloon), "I would not hesitate to wrap my muffler about this six-shooter, and by putting twelve holes close together through the gas-bag where it 'bellies' out, I might thus tear the en-

velop and let out sufficient gas to prevent our being dashed to pieces."

"Well," said Dr. Wells, "I 've been ballooning all my life, but that 's a new one on me, and not half bad, either."

I had spent most of the night previous to our ascension in devising some apparatus for indicating the influence of the earth upon the dip of the magnetic needle, and upon other magnetic apparatus when at a considerable altitude from the earth. The balloon, which was equipped with a long drag rope, was also caused to rapidly rise and fall by alternately throwing out sand and opening the gas valve, and tests were made of the friction of the air on the surface of the balloon in producing a static charge indicated by an electroscope.

In 1892, I had the pleasure of visiting Sir Hiram Maxim at his home in Baldwins Park, England, at the time when he was at work upon his great air-ship; and during my sojourn had the pleasure of taking a short ride upon this steel monster as it passed rapidly over the rails of the experimental track, being driven by the huge sixteen-foot screw propellers. As I recollect it Maxim's air-ship was 126 feet long, weighed about 7800 lbs., and its motive power consisted of two compound steam engines of 300 horse-power each. Sir Hiram has always been a firm believer in the solution of the problem of aërial navigation by means of the application of the aëroplane principle, and I well remember his speaking of the sensitiveness and the helplessness of the balloon, and of his remarking "that you

could no more propel a balloon against the wind than you could make a jelly-fish swim up-stream." And as illustrating the extreme sensitiveness of a balloon, which is nothing more nor less than a huge bubble of gas floating in the air, I would mention an experiment which I tried some four or five times, with the same result. At a time when our instruments showed that we were practically stationary in the air, I took a sheet of gold leaf in my hand, and holding it at arm's length over the side of the car I gently withdrew my hand, allowing the gold leaf to rest upon the air, the inertia of which had not been disturbed, then reaching my hand into a bag of sand, I carefully dropped a handful of sand on the opposite side of the basket. Immediately the balloon with its three passengers, and our extensive apparatus rose rapidly, leaving the gold leaf far below. It seemed to me an extraordinary illustration of the sensitiveness of the balloon. I remember having a long willow wand some ten feet in length which I had used in connection with the electroscope, and after twisting this into a spiral screw, I dropped it over the side of the basket, when at a height of about three-quarters of a mile from the earth. It was a beautiful sight, as the sunlight shone upon the white wood, and it seemed to screw itself through the atmosphere until it reached the earth far below in a manner to at once suggest to me the idea of employing an aëronautical device based upon this principle for making ascensions into the air. This Hélicoptère principle has of late come into considerable prominence in aëronautical work. In this connection I am reminded of a

very interesting effect observed by the well-known aëronaut, Leo Stevens, during a recent trip. When about two miles above the earth he had thrown an empty champagne bottle in an oblique direction, and he was astonished to observe that instead of the heavy bottle falling like a "plummet" it began to describe an ever-widening spiral, until the turns were over 2000 feet in diameter; and on timing its fall he found that it took over three minutes for the bottle to reach the earth. He says it also had an undulating or snake-like movement caused, he believes, by the mountains and valleys over which they were passing.

As far back as 1880, while an assistant at Edison's laboratory at Menlo Park, N. J., the writer devised a system of signaling from war balloons by means of colored incandescent lamps suspended from the balloon or placed inside the balloon, signals being controlled either by the operator in the car or, in the case of the use of small captive balloons, wires were run to a keyboard on the ground by which a code of signals could be operated. It had been my intention to make such experiments during this trip, but it was found impossible for us to carry the heavy batteries with us in addition to our other apparatus, and we contented ourselves with heliograph signaling by means of the mirror, and the sunlight.

It was curious to note by means of the recording barometer that when the balloon was passing over a river or a dark forest the sun's rays had been so absorbed and the atmosphere above had become so chilled as to condense instantly the gas in the balloon, causing

it to fall rapidly, and in passing over arid land which reflected the sun's heat into the atmosphere, we found the temperature was so high as to cause the balloon to rise with very great rapidity. Often, when near the earth, we could tell whether we had descended or ascended by merely noting the change in the size of the shadow cast by the balloon. At our greatest elevation, somewhat over a mile, we were unable to observe mountains or rivers; and, in fact, the earth itself looked like a huge colored map, and it seemed as though we were looking down into a bowl, a phenomena due to the same powers of refraction which causes the sun and the moon to look so much larger on the horizon than when directly overhead. When near the earth we could observe with great distinctness the bottoms of the rivers and lakes as we passed over them.

Upon leaving the earth I observed a curious phenomena due to variation of the density of the atmosphere. A large crowd had assembled to see us depart, and as we passed over the city of Paris in ascending we heard a perfect babel of sound, which soon became a confused medley. There was also a buzzing sound in our ears and a slight feeling of tightness in the chest, which we relieved by opening our mouths and working our jaws for a few moments. Suddenly there was absolute silence caused by the lessening of the pressure on the outside of our bodies, while the internal pressure caused a distension of the ear-drums so that they temporarily lost their sensitiveness. Soon, however, an equilibrium being established, to some extent between the external and internal pressures, our ears began to regain their

sensitiveness and to appreciate sounds of greatest penetration. We heard children's voices, chickens crowing, and the whistles of passing trains.

Although it was November, we were at times forced to take off our overcoats, and at other times we were very glad to put them on again; but, of course, we felt no wind, as we moved along with the wind.

It was interesting to observe the actions of the animals in the farm-yards, and particularly the little chickens, which ran to the mother hen for protection, while the horses and cattle, snorting, bellowing and kicking their heels in the air, rushed madly about as we passed overhead and they observed the shadow of the balloon, or the huge object which they took to be some giant hawk or evil monster. On one occasion when we were dragging our anchor and endeavoring to land, a woman working in the fields became so terrified that she ran around in a circle screaming at the full extent of her lungs, and barely missed being caught in the prongs of the anchor.

We descended at about sunset at a little village called Erchu in the department of the Somme. The country people for miles around rushed toward us and seeing the huge American flag some thirty feet in length which I had borrowed from the Edison exhibit and suspended from the basket, they shouted to one another that we had come across the sea from America. They subsequently told us that they had never seen a balloon before in that section of France, but there were many willing hands to help us land and to pack up our balloon, although we had several rather severe bumps be-

fore finally landing, in one case barely scraping the bottom of our car over the state line of telegraph wires which passed along the highway. We unfortunately came down in a field of wheat which was soon obliterated by the feet of the curious country people, and I had the felicity of paying about 50 francs to compensate the owner, who had become distracted over the loss of the grain which had been trampled under foot. The director of a neighboring sugar refinery entertained us at dinner and afterward sent us in a conveyance, together with our balloon packed snugly in the basket, to the railway station some miles distant, and we returned to Paris much pleased with our journey.

I subsequently endeavored to secure the huge Godard balloon which carried some forty-five people, and was used as a captive balloon during the Paris Exposition. It was arranged that Dr. Rotch, Mr. Lyman, the inventor of the Lyman gun sight, Dr. Wells, and others, seven in all, were to make an ascension and it was our intention to endeavor to go to Russia (a plan subsequently carried out by Count de La Vaulx). I had been watching the meteorological conditions around Paris and the records of the various postal-card balloons sent up from the Eiffel Tower, and I felt confident we could strike a trade wind which would carry us directly across the continent to Russia. We found that owing to repairs being made on the balloon that it could not be secured for six weeks' time, neither could a large balloon which we endeavored to secure from the Crystal Palace in London be had in time, and

as several of us had our passage engaged to go back to America the trip was abandoned.

I present herewith three illustrations of photographs which I made from a balloon in Paris, the pictures being taken at three different heights, approximately 300, 900 and 2000 feet from the ground and looking down upon some twenty-three balloons which were about to be sent up at the time of the International Aëronautical Competition and the Aëronautical Congress held at Paris in 1900.

XII

EXPERIENCES OF TRAVELING IN A BALLOON OVER MOUNTAINS AND RIVERS AND MAKING A SAFE LANDING

BY AUGUSTUS POST

REALIZING that the importance of aëronautics was not appreciated, nor was any organized effort made to assist individual success, the Aero Club was formed in New York City to gather together widely scattered facts, to disseminate knowledge, to receive records and reports and give them proper standing. This club is affiliated with the Aëro Clubs of France and England, and the various clubs in all countries of Europe.

Nearly five hundred ascents were made from the balloon park at the Aero Club of France last year, making an average of two a day during the season; on pleasant days eight or ten balloons would be liberated. It is possible to see a sphere floating in the skies over Paris almost any day during the summer months.

During the visit of Count de La Vaulx to this country last spring, an ascent was planned from Pittsfield, Massachusetts. The *Centaur*, an immense balloon of

55,000 cubic feet capacity, was sent by express to the Pittsfield Gas-works. Arriving early in the morning, large tarpaulins were spread on the ground, upon which the envelop was carried by six men. The sand-bags were filled and placed around in a circle to be attached to the netting to hold the balloon while it was being inflated with coal-gas.

The *Centaur* is the famous balloon in which the world's long distance record of 1193 miles in 35 hours from Paris to Kieff, Russia, was made during the balloon race held by the Paris Exposition in 1900, in the following trips:

Paris to Warsaw (Russ. Pol.) ..	900	miles in	22	hrs.
Paris to Lubeck (Baltic Sea) ...	550	"	17	"
Paris to Breslau (Silesia)	850	"	10	"
Paris to Westervek (Sweden) ..	950	"	23	"
Paris to Emden (Hanover)	400	"	16	"

The valve and neck are separate from the main part of the envelop, and are attached before inflating. The valve rope is made fast, and the ripping cord, which is a rope fastened to a portion of the material, arranged to tear out, leaving a large opening through which the gas quickly escapes when the descent is made, and after the gas-bag is on the ground. This prevents the basket with its occupants being dragged along the ground, if the wind is blowing very hard. It is a very inspiring sight to see the balloon swell up and grow larger and larger, finally assuming the shape of a large sphere, while many men keep continually lowering the sand-bags around it. After it is entirely filled with gas, the

collecting ring is attached to the ropes leading from the netting, and the car is fastened to this ring by four or six stout ropes. The aëronauts then take their places, bags of ballast are taken on board, and when all is ready the men around the basket allow the balloon to rise from the ground a little way in order to balance it properly. If it does not rise some ballast is put out; if it has too much ascensional force more ballast is taken on. Finally, when all is right and the wind is still, the word "let go all" is given, and strange to say, the earth, the crowds, the trees,—all seem to shrink away; there is a slight murmur of voices that grows weaker, a waving of handkerchiefs, until finally all is still. While floating in a current of air, and moving as fast as it does, no breeze is felt, and if it were not for the rising and falling of the recording barometer which shows just how many meters your altitude is, it would be impossible to tell that there was any motion at all. There is nothing to judge by, nor to give you relative change of position.

We sail far over the hills and lakes, the bottoms of which are as clearly visible as the banks around them, a fact that makes air-ships the natural enemies of submarine vessels. The houses look like the toy farms that you buy in stores, the cows like so many stones in the fields, and people are hardly recognizable. Now and then they wave something white and the salute is truly appreciated. Far beyond the reach of anything on earth, with no communication except when we threw small parachutes with postal-cards attached and addressed, to be received later, everything was at perfect

peace, and the feeling one gets is like that of being out on the ocean or in a great forest. Although the wind may be taking us thirty or forty miles an hour, the only sign by which we can tell that we are moving is when we see the round shadow of the balloon below, or when we approach near the ground, for the noise of the wind in the trees sounds like the rushing of water.

After sailing almost two hours, and having had a light luncheon, we chose a good landing-place and prepared to make a descent. The temperature was taken by a thermometer, and the time and altitude determined, whereupon the rope from the neck was made fast so that when the valve at the top was opened and the gas should escape, the bottom of the balloon would not form a parachute and catch the wind. Lower and lower we came, four thousand feet in five minutes, until the guide-rope which hung three hundred feet below touched the tops of the trees and dragged over them. Ballast was thrown out until we gained our equilibrium. We could hear the wind blowing in the branches and could see how swiftly we were moving. When we came to the edge of an open field, the Count cautioned us not to get out of the basket until ordered. He pulled the valve-rope, allowing some of the gas to escape, and we descended lower. When within one hundred feet of the ground, he cut away the anchor which fell, embedding itself in the ground. The balloon, lightened by this much of its load, made an effort to rise again, but it did not have force enough and so descended to the ground. We each held on to the ropes supporting the car, raising our feet from the

bottom of the basket, and did not feel the shock when it struck the earth. The great ball rebounded in the air from fifty to seventy-five feet, dragged the anchor and cleared a stone wall and a clump of trees before it settled again on the ground. The. anchor held firm, the rip-cord was pulled, and a great rent made in the top of the envelop through which the gas at once escaped, leaving the deflated harmless thing spread out on the ground, looking more like an innocent piece of material laid out on the grass to bleach than a marvelous air-ship, that had brought a party of four large men more than forty miles with their baggage and luncheon and all the convenience of air traveling.

The farmers of the surrounding neighborhood came crowding around us asking where we came from, if we were not afraid, and desiring to help us pack up our things.

The barometer registered 1700 meters for the maximum height, and we had traveled over forty miles in two hours from Pittsfield into the state of Connecticut, and landed near the town of Winsted. We loaded up our balloon on a farm wagon and drove to the nearest railway station, where we saw the first account of the San Francisco disaster.

Many ascents have been made and many contemplated. The Aero Club has balloons that are ready for use. Another year will see even greater progress; we will have speed races and contests to see who can remain the longest period of time in the air.

XIII

BALLOONING

By Leo Stevens

OVER twenty years ago I started on my first balloon voyage in a small hydrogen-gas balloon from my native city, Cleveland, Ohio. I never shall forget this small balloon, bulging out to its fullest capacity, and the wind swaying the silken globe in all directions. The story of how I made my first ascent has been told too often, but it was so glorious that I continued ballooning, and the hundreds of ascensions that I have made are sufficient to assure any one of the safety of the sport.

Ballooning, like everything else, requires a man of knowledge and of common sense, and if one keeps his head it is the safest of all sports, and not nearly so expensive as yachting, motor boating or automobiling.

I would recommend a balloon of 35,000 cubic feet for two or three passengers, which, including the outfit, will ascend with a force of about 320 lbs., sufficient for an afternoon sail of 50 to 100 miles. Balloons are not all made of silk; some are of linen, and for ordinary use I would suggest cotton. A fine balloon with up-to-date improvements, made in templets with netting, safety-valve, hose pipe, car, an-

chor and sand-bags, including a ripping section inserted in the envelop, costs only $800. To inflate this balloon for a journey the gas will cost $35, for one afternoon's sport. With the many improvements which have been made in the balloon during the last few years there is no danger of accidents. I have sailed in winds of 72 miles per hour without feeling the slightest motion, though going at a terrific speed. I have always preferred the night for my traveling when I had hopes of accomplishing any great distance. All aëronauts, or people practising the sport, derive great benefit from sailing at night, there being no great expansion of the balloon such as the sun causes during the day. Suppose you are in an equilibrium at 500 meters height when all at once a little cloud masks the sun for a second or two, the temperature in your balloon cools down a little, and if at that moment you do not throw out enough ballast in proportion to the ascensional force lost by the condensation of the gas you will rapidly start descending. It is necessary to throw out just enough ballast, for if you throw out too much you will become too light and go higher. Next moment perhaps the little cloud ceases to mask the sun, your gas heats up again to the first temperature and regains its first lifting power, but having less to lift by the amount of ballast thrown out it now shoots higher into the air. The aëronaut by experience becomes acquainted with this matter and gets accustomed to throwing out ballast at proper times.

Ballooning is a healthful sport. The sensations are indescribable and one never can explain how grand and

refreshing it is to travel in the upper air, where there is no jolting, no wind, no noise, and no sign of fear, and one may be a mile above the earth and moving at great speed. Rivers look like silvery threads, buildings like dog kennels and people like ants. For forty miles the land in both directions is spread before you; mountains and hills resemble level land with the roads seeming straight, no matter how uneven they really are.

Upon descending I have always received a welcome and I assure you, like many others, I intend to continue this grand sport.

In 1901, I had the first dirigible balloon in this country, and to-day we have at least fifteen. It is safe to say that in less than ten years transatlantic air-ships will be in line between New York and abroad. New York will be the world's great air-port and we shall all live to see it.

If I were a millionaire who wished to dispose of my surplus money for the benefit of mankind, I should offer a prize to be paid to the man first accomplishing a feat of this kind to a given point and return.

There will be many styles of machines, the Dirigible, the Aëroplane and the Combination, that is the balloon and aëroplane combined. The experimenters who have been at work both here and abroad have not applied sufficient power, but still they have gone to a given point and returned again.

If the *Oceanic*, or any of our large fast steamers with all their power were to try to cross the ocean with 50 horse-power they would be lamed. It is a matter of power application, and aërial navigation is only in its

infancy. It is making rapid strides, and I expect to see the great feat performed of an air-ship going from New York to France in less than five days.

Every aëronaut should have a compass, a self-registering barometer and a statascope; the barometer gives the height attained, and the statascope the rising and falling.

The inflation is now accomplished in about fifty minutes, and the gas-works in many places both in the East and West can deliver gas at 500 cubic feet per minute, especially in St. Louis where it can be furnished at 800 cubic feet per minute. I recommend that western city as a starting-point for long flights. Its gas has an ascensional power of 44 lbs. to the 1000 cubic foot, which is a little over that of the gas furnished here in the East.

Pittsfield is an ideal place for short flights, and Philadelphia has a good supply and good starting grounds. With all these great facilities, and what we know about ballooning, and the wonderful progress the Aero Club of America is making toward improving the problem of aërial navigation the world will see America lead.

XIV

CRITICAL REMARKS ON PROGRESS[1]

By Charles M. Manly

IT is a notable sign of the kind of attention which aëronautical work is now attracting that a man like Dr. Bell, who has to his credit the accomplishment of such big things, should become so actively engaged in it. As Dr. Bell has already pointed out, the world owes much to Mr. Langley for having taken hold of the subject when it was looked upon as the wild dream of cranks and enthusiasts, and for having made it seem worthy of serious consideration by putting it on a scientific basis. It is no less fortunate that we have to-day such men as Dr. Bell actively engaged in the construction of large man-carrying machines; for the influence of their example causes the work to be looked on by the public more and more seriously all the time.

Dr. Bell has pointed out that one of the advantages possessed by such a slow speed aërodrome as he will be able to construct by utilizing his important invention of tetrahedral cells is the possibility of anchoring such a machine and having it maintained at a height through

[1] A paper presented before the Washington Academy of Sciences, December 13, 1906, and specially revised and enlarged for this publication.

its ability to fly as a kite. This suggests the superiority which such a machine will possess not only as regards safety in case of a break-down of the machinery, but also as regards its use as a war machine. The ability to anchor and remain steadily over a given point will enable the operator or operators to study thoroughly and map out fortifications and the disposition of field forces, as there is very slight probability of so small an object as an anchor-rope being discovered by the enemy; and even if it should be seen, the operator can cut the rope and thus render himself comparatively secure from capture.

As a war machine, Dr. Bell's tetrahedral plan of cellular construction for the surfaces would, I think, present another very great advantage. Such a machine might be badly riddled with shot and yet be able to maintain very good equilibrium, while a machine having large units of surface with large parts in the framework of its surfaces, would be very seriously crippled should a chance shot disable one of the main supports on either side.

It may not be amiss to call attention also to the fact that the operator on any aërodrome or balloon, when at a considerable height, can plainly see submarine boats at any depth in the water. Such machines can therefore be used for determining the number of submarine craft in the enemy's force of harbor defenses, and by keeping the machine circling above a battle ship or a fleet of ships, the possibility of attack by submarine boats would be very greatly lessened. In fact I should think that with Dr. Bell's multicellular machine there would

be no great difficulty in maintaining the operator in the air for hours by simply flying the machine as a kite anchored to the ship.

I trust that Dr. Bell will pardon me for not agreeing with the explanation he suggests of the very interesting fact noted in regard to the propulsion of the "Catamaran Life Raft" by means of aërial propellers, namely: that the raft advanced against a sixteen-mile breeze, although in a calm it was able to make only something like four miles an hour.

It seems to me that this ability of the raft to advance against a sixteen-mile wind is not due to the difference between the momentum of the raft and the momentum of the air, but to the fact that the raft presents very little resistance to the wind, while the propeller, being revolved at a high rate of speed by the engine, tends to advance in the air at a speed proportionate to its pitch, multiplied by its number of revolutions in a given time. I have no doubt that the raft would have advanced against any wind of a velocity less than that which would be created by the slip of the propeller revolving in still air at the same speed as when driving the raft. In other words, if the propeller had a pitch, let us suppose, of one foot (that is, tended to advance through the air one foot for each revolution, or forced the air backward one foot for each revolution), such a propeller revolving at the rate of a thousand revolutions a minute would, in a calm, create a back wind of a thousand feet per minute, and of course a propeller of two-feet pitch would create a back wind of two thousand feet per minute when revolving at the same speed. Such

a propeller, then, of two-feet pitch, revolving at this speed, when mounted on a raft should be able to prevent the raft being blown backward in a wind of somewhere near two thousand feet per minute. I have no doubt that the back wind due to the propeller in Dr. Bell's experiment was of an even higher velocity than two thousand feet per minute.

Few of us can conceive of the affairs of the world ever being different from what we are accustomed to, but there are certain definite effects which we can be fairly confident will follow definite changes. I am not a prophet, nor the son of a prophet, but I feel safe in venturing a conservative prediction in regard to one of the effects of aërodromic work in the next few years. We may not be able to make it a general vehicle of transportation, as some enthusiasts predict. While unwilling to define the limits of the possible, I certainly do not expect such results very soon; but I have no hesitation in asserting that the attainment of the ability to fly, say three hundred miles,—a degree of success now practically certain to be attained within five years—will, at whatever risk of danger to the aëronaut, have as important an effect on warfare as the advent of wireless telegraphy, and a far greater one than the perfecting of the submarine boat or the Whitehead torpedo, both of which, even now, are causes of the greatest concern to the officers of even the last and largest and most expensive battle ship.

It is interesting in this connection to learn, what I have just been told on good authority, that a prominent admiral of the navy, who has just retired, is planning

to devote his time to a thorough study of aërodromics, foreseeing, as he probably does, the early advent of the flying war machine, which, there seems ample ground for believing, will prove to be the most important single step in the progress of the art of war.

I am pleased to hear Dr. Bell state publicly his confidence in the accuracy of the reports of the success of the Wright Brothers, for I myself have had every confidence in them and have thoroughly appreciated the motives which have prompted them to withhold a public demonstration of their machine, until business arrangements can be completed which will enable them to reap the financial profits which their success so richly deserves.

I trust that I shall be pardoned for emphasizing Dr. Bell's statement as to the importance of the fact that the Wright Brothers have flown not only once, but many times. The fact that a machine has flown successfully and carried a man not only a few hundred feet but something like twenty-five miles, will, when its significance is realized, have the greatest effect on the future progress of the work.

I have always wondered why it is that the more prominent polar explorers have been able to secure very large sums of money for use in their attempts to reach the North Pole, yet no public benefactor has seemed ready to render substantial financial assistance in the solution of this problem of opening up for mankind the great aërial highway, which, to me at any rate, seems of so much vaster importance to the world. The only reason I could assign for this has been, that while the

existence of such a point as the Pole is capable of mathematical demonstration, the possibility of a successful flying machine has seemed a subject not for science, but for dreams.

It seems to me, however, that the fact that success has already been achieved by the Wright Brothers should put the whole problem on a very different footing, and convince even the skeptical that the question of success is now merely a question of degree. As people of means who wish to perpetuate their name can do it in no better way than by assisting in a substantial manner in the progress of scientific investigation, they will surely now be ready to furnish the funds necessary to ensure most rapid progress in the work.

We must remember that in these days work of this kind progresses by leaps and bounds. It is barely seven years since the first annual Automobile Show was held in Madison Square Garden, New York. No attempt was made to utilize the galleries of the Garden and practically the entire area of the main floor was given over to a track which was used for demonstrating to the audience the fact that an automobile could be stopped in a very much shorter distance than a horse-drawn vehicle going at the same speed. The management in charge of this show, in order to fill up space, even provided seats which were arranged for the convenience of the visitors. Last winter, just six years after that date, instead of one show occupying only a small portion of the Garden, there were two shows of about equal size held simultaneously in New York, and the one which was held in the Garden not only filled it

from cellar to roof, but the streets all around were filled with demonstrating machines. Instead of seats being provided, it was necessary to have policemen to see that the people followed the proper circuit of the building so that the crowd should be kept moving, and all might therefore have a chance to view the exhibition. As the outcome of an industry which six years ago amounted to nothing, we have in the United States to-day, about one hundred million dollars invested in approximately seventy-five manufacturing establishments which, during the year just closing, have produced more than 50,000 machines, and instead of the automobile being ridiculed by the cartoonist as a chimerical dream, it has become the chariot of the millionaire, and the freight truck of the industrial world, hauling goods and ore from the steamship piers and the mines.

Realizing that this enormous progress has been made in the short period of less than a decade, it is only a pessimist of the deepest dye who would dare predict that the next decade will see not only enormous strides in the progress of aërodromics, but also the aërodrome itself an important factor in human affairs.

For thousands of years man was content to travel no faster than his ancestors, but the advent of the steam locomotive followed by that of the electric car has quickened the inventive genius of the world to its very core. Now man, not content with being confined to travel at a high speed on a definite route marked by parallel steel rails, has quickly taken up the automobile which can follow not only the multitudinous roadways, but, if necessary, blaze out its own way through

the fields and woods. Instead of having his ambition satisfied by this multiplication of his possible paths, he still thirsts for more freedom, and will not be satisfied until he has opened up for himself access to the highways of the air, which are limitless in all directions and on which speed laws enforced through police traps, if not impossible, will at least be most difficult to maintain and enforce.

While for many years I have felt the deepest interest in aëronautical matters, it was only in 1898 that I first became actively engaged in the work. I had the pleasure and the honor of being associated for some seven years with the lamented Secretary Langley as his assistant in direct charge of the experiments which he conducted at the Smithsonian Institution. Dr. Bell has already referred to the fact that this later work which Mr. Langley conducted was carried on for the Board of Ordnance and Fortification of the War Department. As you are all no doubt aware, it is the custom of the War Department in conducting important tests to exclude, not only the general public, but also the representatives of the newspapers; and in undertaking this work for the War Department, Mr. Langley made a very definite agreement that the public should be excluded from witnessing the construction of the aërodrome and the tests of it, though in the interests of science he retained the privilege of later publishing whatever part of the work he might deem of importance to the scientific world. It could not be foreseen at that time that the carrying-out in good faith of this agreement would bring upon him the bitter animosity

of the whole corps of American newspaper writers who would vent their ill-will in ridicule and in censure for failure to achieve complete success.

As those of you, who followed the newspaper reports during the experiments in the summer and fall of 1903, will recall, the large house-boat, on which were stored both the large machine and a duplicate of it on a smaller scale, was carried down the Potomac River in July and anchored at a point about forty miles from Washington. The first experiments which were made were conducted with this model, which was an exact duplicate of the larger machine, but of exactly one quarter the linear dimensions. The object of the tests with this model was to determine whether the balancing of the large machine had been correctly calculated from the results of the many previous tests of the steam-driven models of approximately the same size, but embodying important differences in certain details. I will not burden you with an account of the long series of exasperating delays encountered, delays almost entirely brought about by the very unusual weather conditions which could not be foreseen and provided against; I will only say that the several newspaper representatives who went down the river early in July, and remained stationed there for several months in a malarial district on the Virginia shore, and who had to row somewhat over a mile and a half in order to get within close range of the house-boat which was anchored in the middle of the river, were naturally not very favorably influenced, either by the fogs and high winds, or by their necessary exclusion from all real

knowledge of the work going on within the houseboat.

I can not emphasize too strongly that there was neither fault in design nor inherent weakness in any part of this large aërodrome. The whole machine had been subjected to the most severe tests and strains in the Institution shops in the endeavor to find any possible points of weakness, and had shown itself able to withstand any strain it would meet in the air.

The experiments themselves convinced both Mr. Langley and myself that it would have been better to have conducted them over land rather than over water, as we would thereby have avoided a great deal of expense, and the major part of the delays and accidents which were encountered; yet it must be remembered that, in work of this kind, experiment is the only sure guide, and that aftersight is always much clearer than foresight. It is my personal opinion that had the experiments been conducted over the land instead of over the water, not only would the funds which proved inadequate have been more than ample, but success would have been achieved as early as 1902, instead of what the public has judged to be failure in 1903.

Dr. Bell has told you that in the last experiment the aërodrome was broken to pieces through the ignorance and carelessness of the tugboat men in getting it out of the water. It was almost heart-breaking to look at the wreck that they made of it; but although Mr. Langley found himself without funds for making further experiments with the machine, yet at my earnest solicitation he allotted sufficient money to enable the frame to

be repaired so that it is practically as good as new and stands to-day completely assembled with its engine and everything to enable it to fly, except a new set of supporting surfaces.

It has been generally supposed that the work has been abandoned, and this idea has been strengthened by Mr. Langley's death, but I think I can assure you that the work is not abandoned but merely temporarily suspended, for it is my purpose, at the earliest moment that I can possibly spare the time for it, to reëquip the aërodrome with proper supporting surfaces and, using the same launching apparatus, to give the aërodrome a fair trial, this time over the land instead of over the water. I feel certain that it will fully demonstrate the correctness of its design and construction, and crown Mr. Langley's researches with the success which they so richly deserve; and I trust that the day that this will be achieved is very near at hand. It was the launching apparatus, all will remember, which in both of the experiments caused the accidents that prevented any test of the aërodrome itself. These accidents were not due to defects in the design or fundamental construction of the launching apparatus, for the smaller apparatus of exactly the same design had been used more than thirty times for launching the smaller machines and without a single failure. Certain minute defects in the releasing mechanism were the sole cause of the trouble.

It has been very generally supposed that in his experiments Mr. Langley used exclusively what may be called "single tier" surfaces, and that he did not recog-

nize that the superposing of the lifting surfaces presented certain great advantages, not only as regards ease of construction and strength, but also in reducing the size of the machine. This general impression is due to the fact that all of the photographs of the machines in flight which he published officially, and also those published by the newspapers, have shown the machine as equipped with "single tier" surfaces. I may say, however, that as early as 1890, and onward from that time, until the work was temporarily suspended in 1903, Mr. Langley experimented with superposed surfaces, the first experiments of course being with very small models having their motive power furnished by means of stretched or twisted rubber. The same large, steam-driven models which flew so successfully in 1896, the first flight of which Dr. Bell has just spoken as having witnessed, were, in 1899, equipped with superposed surfaces and were tested in free flight during the months of July and August.

The quarter-size model of the large aërodrome driven by a gasolene engine, which was first tested in 1901 and later in the summer of 1903, was also equipped with superposed surfaces, but in the test of August, 1903, which was witnessed by the newspaper representatives, the "single tier" surfaces were used. The prime reason that the large aërodrome was equipped with the "single tier" surfaces was that the best flights of the models were with such surfaces, and although in the beginning it was planned to build superposed surfaces for the large machine later, the early depletion of the funds provided by the Board of Ordnance

and Fortification made it imperative to utilize what had already been constructed, as it was with the greatest reluctance that Mr. Langley continued the work with the funds of the Institution, and all expense which could be avoided was carefully guarded against. I have thought it well to mention this fact, as I have had many inquiries as to why it was that Mr. Langley never realized that the superposed type of construction for the supporting surfaces presented important advantages.

It was my duty while connected with the Smithsonian Institution to prepare answers to the large number of letters on aëronautical subjects which were constantly received. While some of the writers sought advice, others offered it; and a large number of the letters indicated that the writers believed that the problem of constructing a successful machine required the discovery of some "secret." In view of this experience I have thought that it might not be amiss to emphasize that there is no secret which needs to be discovered in order to build a successful machine, but that success is to be achieved by laying out a good design based on a proper knowledge of the laws of aërodromics as at present known; next, by giving the greatest care to constructing the parts as strong as possible for the permissible weight, and then trying the machine not only once, but again and again, under conditions presenting the least possible danger to the operator.

In this connection attention may be called to the fact that when a machine is planned and the weight of the different parts is allotted so that the total weight shall

not exceed a certain proportion relative to the supporting area, the experimenter need not be surprised to find, when he has completed his machine, that it weighs forty or fifty per cent. more than he has calculated; for in carrying out the innumerable details of construction small increases in weight at almost every point finally increase the total weight surprisingly.

In all of the accounts which I have lately seen of the experiments of the Wright Brothers, no mention has been made of the fact that the success of the Wrights has been built on the very valuable work of Mr. Chanute, who for many years carried on at his own expense work in the construction and testing of gliding machines, and who, I understand, not only furnished the Wright Brothers with the design for their first gliding machine, but also placed at their disposition his own machines with which they made their initial gliding experiments. There is perhaps no one who has made a closer study and has a more thorough understanding of the whole subject of aërodromics than Mr. Chanute, and I should like very much to see him given due credit for the very important work which he has done.

XV

AËRIAL HIGH SPEEDS

By Prof. David Todd, Ph. D.
Director of Amherst College Observatory

WHEN, in 1890, the late Professor Langley was experimenting at Allegheny with his plane-dropper and other most ingenious mechanisms of his own devising, I chanced to visit him on an astronomical errand. The results he had already reached, surprising and almost paradoxical as they seemed, led me to devote a good deal of attention to aërial experimentation for the next few years. Aëroplanes of a multitude of shapes and materials were tried, a room in the top of the old College Tower at Amherst having been fitted up as a launching laboratory.

From the first my faith was anchored to the ultimate success of some type or other of aviator machine, for balloons and dirigible cars seemed to me useful merely as passing stages on the way to the perfected type of aërial engine. Subsequent developments have only served to confirm this opinion.

What shall be the design of that machine is not yet fully settled, and it never will be settled by theorizing. Only experiment, in the laboratory and the open air,

can ever determine it. The question now, as I understand it, is largely one of machine design, embodying sound physical principles already ascertained and not exceedingly difficult to apply.

We should expect a difference in design among different inventors; that is quite inevitable. The best thing to do, apparently, is to follow nature. This does not necessarily tie us up to the vibratory-winged type of machine, as so many inventors appear to have thought. Nature is lavish with suggestions of an altogether different sort, and her cue is by no means concealed.

I have been a believer, too, in results from successful and unsuccessful models—models often of the least expensive and most rudely constructed type. It is much more important to provide the means for accurately estimating their efficiency. Many such machines are necessarily lost or shattered; but the suggestions they afford the experimenter by their imperfect flight are just as useful as those obtained from large machines, besides being vastly less dangerous and costly.

Ten years ago, some type of successful aviator machine seemed near at hand. There was every reason to believe that we had all the data necessary to design and build a machine that would conquer the realms of the air. Leaving this to others to invent and work out to the finality, I addressed myself to the question of means of alighting in safety from such perilous flights. The necessary devices for attaining this end were worked out experimentally in simple and successful form, and I feel satisfied that alighting from any aërial height

can be effected in any open space with perfect ease and without shock. This feature of the research, a side issue it might be called, gave me many hints as to the best design for the flying machine itself. What that design is, I should find difficulty in describing without drawings, and it is quite possible that I should modify it materially in practically working it out experimentally to the finish. I may say, however, that it is radically different from the type of Professor Langley's aërodrome, which always seemed to me to have salient defects, or deficiencies perhaps, of a sort to handicap, if not actually preclude, successful flight in non-homogeneous air.

But before we solve the problem of the flying machine, we should, in logical order, attempt the simpler one of skimming the surface of still water. Simpler and easier this problem is, because for buoyancy the heavier and more massive water acts instead of the lighter and more facile moving air. Trial speeds for water-skimming, therefore, need not be anything like so great as are necessary for aëroplane support of a moving body in free air alone. I began experimenting on these lines in 1901.

First the physics of the hydroplane must be investigated experimentally, much as Langley did for the aëroplane.

Second, the efficiency of different forms of screw must be ascertained, including the best number of blades, their individual shape, and relative arrangement about the propeller shaft. This investigation is well advanced. Only the most rigid experimentation

can ever determine these points—mere theory is practically useless. Then, too, the number of propellers is most important—the number of pairs, rather, as they should be disposed symmetrically about the median line of the machine, and revolve in opposite directions.

Third, it is necessary to investigate the many means of diminishing skin friction of hydroplanes. This, too, is a purely experimental research, only in part complete.

Working with such models as I could get together, I have satisfied myself that no form of water-skimmer, —or hydrodrome, if we may so call it—will ever succeed, if we depend upon the water alone for our reaction, at least not until the viscosity of water is in some way reduced or neutralized, or until we have discovered some happy way of dipping a surface into water without getting it wet. Of all the water-reaction devices that I have tried, none succeeded satisfactorily because of setting up wave motion which in itself was a great obstacle. So I came to the conclusion that, in order to disturb the water surface in the least possible degree, the water must be used for gliding support only; and the shape, number and distribution of the hydroplanes must be adjusted experimentally to meet the essential condition of a minimum disturbance of the surface water.

For driving the propeller shafts, nothing is better than four-cylinder gasolene engines; and in my opinion the velocities within reach of the hydrodrome may easily double that of any water craft yet constructed, and with much less power than is now expended in

driving the swiftest motor boats. It is not easy to overestimate the significance of such a result in navigating shallow rivers and the glassy tropical oceans.

If, however, for any unanticipated reason, this question of water-skimming should prove to be incapable of trying out to ultimate and gratifying success, *a fortiori* it will be quite futile to push experiment along the more difficult line of a practical aëroplane machine which must derive its buoyancy solely from the vastly more mobile air while gliding swiftly through it. If we cannot do the one, it is useless to expect to do the other.

My contribution to the ultimate success of aërial navigation during the past year has been slight; I have been hoping that the problem would be solved in final form by other and abler experimenters. Meanwhile, however, I have gone on improving my design, and imagining it at work; trying not a few unsuccessful experiments with it, and modifying the conception suitably therefrom.

One very certain obstacle which we shall meet, not only in navigating free air, but in water-surface gliding, is the lack of homogeneity of the air itself. Swift transit through such a medium precludes all possibility of a rigid machine, either as to its plane system, or its propelling mechanism. The problem is a little like that of designing an automobile to drive over rough roads with the least possible jar and wrenching of its mechanism, let alone discomfort to the passengers. We must remember that for velocities above sixty miles per hour, an aëroplane system passing from air of mean density

to an adjacent mass of density much greater or less than the mean, will experience a shock like that imparted by a huge rubber-faced mallet or other solid substance. Flexibility and resilience of design must, therefore, be provided at every point.

Among the more serious problems of the hydrodrome is its tendency to ricochet. The capers of a model are not especially disturbing; but were the full-sized, high-speed machine of some tons' weight to go frisking about in this fashion, its passengers might wish they had chosen some other form of conveyance. I do not, however, regard this tendency to ricochet as beyond the reach of experiment to subjugate, though it has presented the possibility of more trouble than other elements of the design so far elaborated.

To facilitate future work along these lines, I have acquired during the past year a suitable property on the north shore of Buzzard's Bay, where abundant shore privilege is available, and hydroplane experiments may, I hope, proceed unhampered by suburban curiosity.

XVI

EXPERIMENTS WITH KITE-SUSTAINED AËROPLANES

By William A. Eddy

I HAVE carried out here at Bayonne, N. J., certain experiments with kite-sustained, or rather kite-suspended aëroplanes without motors, small models one or two feet in diameter, with a view to testing the laws of sailing flight in various ways with various designs. These experiments have been carried on here for many years, and the results have not yet been reported to the public or to the experts in aërial navigation air-ship construction. The trials, several hundred in number, have evolved the truth that the aëroplane when launched in the air at a height of a thousand feet behaves differently at different trials, and that this difference in effect is due mainly to differences in the angle of inclination at the moment of starting. For example at 30th Street and Avenue C, Bayonne, I dismissed a six-winged aëroplane, two feet in diameter, at a height of 600 feet. It was dropped aloft by means of a hook and ring. When the kite-line was hauled in about 30 feet and then suddenly paid out, the aëroplane, suspended in a perpendicular position with its forward edge upward, was launched into the air, because the

aëroplane had sufficient supporting power to enable it to lift itself, as it were, off the hook. Of five trials one was decidedly successful. The aëroplane floated over Bayonne for half a mile to the shore of Newark Bay, where it dropped into the water a quarter of a mile off-shore, and was recovered by two boys who happened to be out with a rowboat. This most successful of the five flights, was of course the last one made for the day. Previously, two other flights were made, the aëroplane landing in open ground about a quarter of a mile away. In the two other flights the aëroplane was upset at the start, and turned over and over without semblance of sailing. The two failures seemed to arise from a defective angle of inclination at the moment of starting. Now let us go into the question of the method of starting the sailing flight. The first discovery I made was that if the aëroplane does not consist of superposed planes, like the Ludlow design which I saw at New York,—that is, if it is a single plane like the Eddy kite, it must be suspended by its forward edge, its tail receding, otherwise its start will be so bad that it will not float, but will turn end over end. The law of gravitation—the fundamental and unchangeable law—is, that all aëroplanes must have a weighted forward edge. In the Ludlow experiments, which were exceedingly important, the weight of Mr. Hamilton was so adjusted that on moving forward his weight would cause the cell-like aëroplane to move forward with accelerating velocity. There is no doubt that the cell-aëroplane has the power to cut to pieces gusts, and dissipate or annul the effects of such gusts. The tendency of gusts

is to upset the aëroplane. It was owing to such a gust that Lilienthal was killed with a single-plane machine. The Bell tetrahedral kite shows remarkable power to conquer gusts. I had the honor of flying one of the Bell tetrahedral kites at St. Louis at the request of Prof. Bell's agent at the great exposition there. The wind was very gusty, but the kite sailed throughout the gusts with absolute steadiness. The many edges of the triangular cells of Bell's kite cut to pieces and equalize any irregularity of pressure.

The single plane aëroplane, after the type of the bird, is unquestionably superior, because, owing to its spread of surface and lightness of construction, it will float against light winds when the cell kite would descend, owing to its weight. But the use of a stable single-plane aëroplane involves questions of such delicate balancing like that of the condor, the vulture, or the sea-gull—watch the sea-gulls from the ferry-boat deck—that the cell-kite aëroplanes must take the lead, and in some respects they will always hold it. I believe, however, that the single plane of the sea-gull will be the last achievement of the art of aërial sailing with rigid wings. I notice that in heavy gusts, even the sea-gull with all his magic skill is compelled at times to tack sidewise, and to advance against the wind with an irregular struggling motion.

But the art of single-plane flying is far too difficult for man to master at the pioneer stage of the art of flying. We must begin with the cell devised by Stringfellow in 1866. Langley, whose aërodrome photographed by Bell while the aërodrome was aloft, had

passed at that time all previous records for six hundred years, as far as known,—tried the most difficult part of the problem first—the use of four rigid wings as planes. We must begin with the convex-planes and the rectangular cell tried by Ludlow. Kimball has shown by using the Eddy kite that an astonishing amount of supporting force is possible by means of the single plane, but Lilienthal's death shows that the single plane is far too delicate for us to handle with safety. The death of Pilcher in England was due to the use of a single-plane apparatus, the guiding rudder of which broke. When Pilcher visited me at Bayonne in 1893, or 1894, I sent up an Eddy kite and he was delighted. He said: "It floats! It floats!" but I explained to him that it would easily upset. Had he used the cell form tried by Ludlow such an accident as that which caused his death could not have happened, unless the whole cell construction were weak. I would not recommend the use of even a cell aëroplane where the guiding rudder at the rear is also a balancing weight, because in case of accident the result would be loss of life. It will be noticed that Lilienthal risked his life with a balancing rudder, but his death was due to wide outspread wings and short distance fore and aft, with great danger due to the delicacy of the balance. This single-plane method calls for the wonderful guiding power of the bird which we can not hope to equal for many a decade, but with the cell-form the approach of aërial navigation seems close at hand, as shown by the experiments of Ludlow, Chanute, Wright Brothers and Santos-Dumont.

XVII

THE USE OF KITES AND BALLOONS IN THE U. S. WEATHER BUREAU

By Oliver L. Fassig, Ph.D.,
Research Director, U. S. Weather Bureau

SINCE the establishment of the Weather Bureau in 1870, the study of the atmospheric conditions prevailing over the United States has been steadily and rapidly advanced. From a small organization numbering less than a hundred officials, the Bureau has grown to be a complex organization including several thousand members who are engaged in daily collection and dissemination of data in every State and Territory of the Union, and in neighboring countries. The aim of the Chief of the Bureau has always been to make the observations collected and reduced by this army of observers and officials of practical use to the commercial and agricultural interests of the country. Until within a few years ago the study of the conditions of temperature, pressure, humidity, and wind velocity and direction, had been confined almost entirely to the surface of the earth, and, to a limited extent, to conditions prevailing on mountain peaks. The time has come when it is essential to the further progress of our knowledge

of the weather, and to the improvement of the art of weather forecasting, to learn more about the daily changes which take place in the atmosphere at levels high above those in which we live. The forces which control our storms, cold waves, and, in general, all the phenomena of our weather, have their freest and fullest development in the lower and intermediate cloud levels. The paths of storms and their intensity are greatly modified by surface conditions, such as mountains, land and water surfaces.

The necessity for a better knowledge of conditions and changes which take place from hour to hour, from day to day, and from one season to another, at all attainable heights above the earth's surface, has directed the attention of meteorologists to the study of the most efficient means of reaching these elevations either in person, or by means of instruments capable of carrying to these elevations self-recording thermometers, barometers, and other instruments. This activity of meteorologists in the exploration of the upper atmosphere, though covering a period of scarcely more than a decade, has already resulted in the organization of special services for upper-air exploration in at least a dozen different countries. The records thus far obtained give excellent promise of fruitful results in the way of a better understanding of the physics of the atmosphere, and hence encourage the hope of advance in the applications of this increased knowledge to the practical affairs of life.

The method, long in use, of making personal ascents in balloons, and obtaining direct readings of atmos-

spheric conditions, though still employed to a moderate extent among meteorologists, has been largely superseded, owing to the comparatively great expense involved in such ascents. Attention is now mostly directed to the employment of kites, and of paper or small rubber balloons capable of carrying light and ingeniously constructed self-registering instruments to elevations varying from a few thousand feet to fifteen and even at times to eighteen miles above the earth's surface.

Three years ago Prof. Willis L. Moore, Chief of the Weather Bureau, planned and began the establishment of an observatory upon the summit of the Blue Ridge mountains in northern Virginia, near the village of Bluemont. The work of the observatory staff is to be confined to researches into the physics of the atmosphere, with special reference to the relations existing between solar activity and terrestrial weather conditions. A prominent place in the plan of work was given to the exploration of the atmosphere by means of kites and balloons. At the present time the necessary buildings and equipment for carrying on this branch of the work are completed, and considerable experimental work has already been done.

The kites employed at the Mt. Weather Observatory are nearly all of some modified form of what is known as the Hargrave box-kite—a form which has in the main yielded the best results. These vary in size from 5 feet square to 10 feet square, with a lifting-surface of about 40 square feet to 150 square feet, and weigh from 6 lbs. to 14 lbs. The kites will fly without diffi-

culty with winds exceeding 10 or 12 miles per hour at the surface; with winds of less velocity it is difficult to raise them through the lower layers of the atmosphere. By carrying the kite to a considerable distance from the reel, and then rapidly reeling in, an artificial wind is frequently created of sufficient strength to lift the kite to levels where the natural wind is sufficient to sustain the weight of the kite and instrument.

The kite line at present in use at the observatory is made up of steel piano wire in thicknesses of 0.028 and 0.032 of an inch. The total length of the line is for the present 20,000 feet, although this will soon be increased to 40,000 feet or more. By these means light self-registering instruments have been raised to heights of 12,000 feet above sea-level, and have brought down valuable records of temperature, pressure, humidity, and wind velocity. Higher elevations will doubtless be obtained upon the completion of the larger power reel soon to be constructed for this purpose.

Recently, at the Prussian observatory at Lindenberg, an elevation of 21,000 feet was attained. Six box-kites were attached at intervals to a line of steel wire 9 miles in length; the temperature at the station was 41° Fahr., and at the upper kite 13° below zero. The wind velocity increased from 18 miles per hour at the surface to 56 miles per hour at the maximum elevation. The attainment of heights such as these involves the use of considerable power, and is attended by more or less risk to life and property should the kites break away and drag across the country a steel wire several

miles in length; the risk is especially great in the neighborhood of large cities with their network of wires for electric lighting and power.

The kite promises to develop into a scientific instrument of increasing usefulness. It already has an established place in the equipment of meteorological observatories.

The instruments used with kites—called meteorographs—generally register changes in temperature, pressure, humidity, and wind velocity. They are necessarily very light in weight and of small compass; great ingenuity has been displayed in securing these two essential qualifications, while at the same time retaining the necessary rigidity to withstand considerable rough usage without impairing the accuracy of the instruments. They are generally made of aluminium, and vary in weight from 1½ to 3 lbs. The instruments, though similar in their essential mechanism, are of many different designs; some of these are shown in the illustrations.

At times of light wind, when the velocity is not sufficient to lift a kite, or when it is desired to reach greater elevations than is possible by means of kites, balloons of various forms are employed. For moderate elevations, up to about 10,000 feet, captive balloons have been used to advantage. For a time the kite-balloon invented by the German army officer Sigsfeld found favor among the Germans. The capacity of this form of kite-balloon in use at Mt. Weather is 75 cubic yards, and it has a free lifting power of about 75 lbs. when completely filled with hydrogen. When the

winds are very light, elevations of 5000 feet to 6000 feet may be reached by the use of a wire of about 0.04 inch in diameter. Owing to the great expense involved in the frequent use of so much hydrogen gas, and to the risk of loss of the balloon and instruments in the event of a sudden increase in the wind, the use of the kite-balloon has not become general. Recent experiments have demonstrated the practicability of employing the ordinary spherical balloon of 10 to 20 cubic yards capacity, or of two or three smaller rubber balloons attached to very light wire (0.016 to 0.020 of an inch in diameter). Elevations of 10,000 to 12,000 feet have been attained by the use of these small balloons, while the risk of loss has been materially reduced.

For attaining elevations above 12,000 to 15,000 feet, kites and captive balloons give place to small rubber balloons of 2 to 4 cubic yards capacity, or to larger paper balloons, which are filled with hydrogen gas and liberated after the meteorograph has been attached. The use of these balloons has been remarkably successful, and they are now quite generally employed. Some extraordinary records of low temperatures have been obtained by European meteorologists, and in this country by Mr. Rotch, Director of the Blue Hill Observatory. After liberation the balloons rise rapidly to elevations of five to fifteen miles, and at times even to greater heights, landing within an hour or two, at distances varying from a few miles to two or three hundred miles, depending upon the velocity of the upper air currents. A card is attached, giving instructions

to the finder to return the balloon and apparatus. The records obtained in this manner have shown variations and extremes in temperature at great elevations hitherto unsuspected. In a flight from St. Louis on January 25, 1905, under the direction of Mr. Rotch, a temperature of 111° Fahr. below zero was recorded at an elevation of about nine miles. One of the surprising results of the use of free balloons, or pilot balloons as they are called, is the small percentage of loss of instruments and records. Out of a total of over seven hundred liberated in Europe in the course of two or three years, all but one in a hundred were recovered. All of twenty-one sent up from St. Louis by Mr. Rotch in May of this year were eventually returned to him. These figures conclusively demonstrate the practicability of this method of exploring the higher levels of the atmosphere.

Preparations are now being made by the Chief of the Weather Bureau to inaugurate a much more general use of these pilot balloons in investigations of special types of weather in the United States. Balloons will be liberated simultaneously at ten to twenty selected Weather Bureau stations surrounding typical weather systems, such as storms, cold waves, hot waves, etc. The records thus obtained, when studied in connection with simultaneous observations made at the surface of the earth, must add greatly to our knowledge of the movements of storms, and increase the practical applications of such knowledge to commerce and agriculture.

Among the additional special problems to be solved

by these means may be mentioned: the character of the daily and seasonal fluctuations in temperature, pressure, humidity, and wind velocity, at great elevations above the earth's surface; the rate of increase or decrease in the values of these factors during the passage of different weather types; the collection and study of data bearing upon the general circulation of the atmosphere.

The great variations in temperature, pressure, humidity, and wind velocity, recorded by the meteorographs at great elevations, make it necessary to test the accuracy of the instruments with the greatest care. The equipment at the Mt. Weather Observatory provides for a careful verification of these meteorographs to the lowest temperatures and pressures experienced at the highest elevations likely to be reached. In order to test these instruments simultaneously at very low temperatures and low pressures, as they exist in nature, a large copper vacuum chamber, connected with an air pump, and containing a long coil of copper tubing, has been installed at the Observatory. Liquid air is poured into the copper coil, and at the same time the air may be removed from the chamber to any desired pressure. For the manufacture of the liquid air necessary for testing the thermometers at very low temperatures, a Norwalk compressor is employed. After compressing the air to about 2500 lbs. to the square inch, it is led successively into a small steel cylinder for removing impurities, into another for extracting the moisture, and into a third for removing the carbonic acid gas. The purified air is then led into a Bradley-Marvin liquefier.

The hydrogen gas used at the Observatory for inflating the balloons is obtained by means of a Riedinger electrolyzer. This consists of a series of about ninety-five corrugated cast-iron plates about two feet square, separated by sheets of asbestos. The plates and asbestos sheets are compactly pressed together to render the battery water-tight. The system is then filled with pure water to which is added a ten-per-cent. solution of potash. The corrugated plates and the asbestos sheets are perforated in the two upper corners. These perforations form continuous tubes—one for carrying off the oxygen of the electrolyzed water which is liberated on one side of each plate, and the other for the hydrogen which is collected on the opposite side—upon passing a strong electric current through the system.[1] The two gases are then stored in their respective tanks for future use as occasion may require. With a current of about 40 amperes, and a voltage of 220, the electrolyzer yields about 54 cubic feet of hydrogen and 27 cubic feet of oxygen per hour.

The power necessary for running the compressor, the electrolyzer; the motor for the kite reel, and for lighting purposes, as well as for the general machine-shop uses of the Observatory and grounds, is furnished by a 35-horse-power gasolene engine.

[1]Another perforation at the bottom of the plates and asbestos sheets admits the water to be electrolyzed.

XVIII

RUBBER MOTORS AND FLYING MACHINE MODELS

BY WILBUR R. KIMBALL

AFTER a short apprenticeship in flying kites, the experimenter in aëronautics on a small scale will be brought to the question of motive power for driving various pieces of apparatus through the air.

A little systematic work will develop evidence of the fact that twisted rubber bands afford the most simple means of developing very small powers. A twisted rubber band is stored power in the more common use of the term, and permits of a comparatively simple method of measurement and observation. While the per cent. of energy absorbed and of that returned vary with different loadings, with the age of the rubber, and with the duration of a test, fairly satisfactory results may be obtained with such apparatus. Although the weight per foot-pound of energy stored is considerable, such stored power may be returned at a speed that brings the delivery of foot-pounds per second up to a point where the weight per horse-power will compare favorably with the gasolene motors in general use. Should a device provided with rubber-

driven screws not be quite equal to lifting itself free from the earth, a slight reduction in the diameter or pitch of the screws would result in an increase of speed and delivery of power that would probably launch the apparatus into the air. The argument advanced against small rubber-driven models as a guide for larger construction: that they are usually erratic and seldom act twice alike, is perhaps true in the larger number of instances, but this is evidently a fault of design, and does not disprove the suitableness of such apparatus for demonstrating many of the fundamental principles in aëronautics. After experimenters had labored for years, and had proven that an apparatus heavier than air could be made to lift itself into the air, it was found that the real problem of equilibrium and control was the more difficult. To demonstrate these principles, translation from one point to another, and absolutely free flight are essential. The rubber-driven model is a means to this end, at once efficacious and easy of construction. Strips of rubber soon tear at the edges when subjected to repeated twistings. Ordinary package or wrapper bands soon develop weakness at the seams or splices. A seamless tube, or one with the seam running the whole length of itself, soon indicates its superiority over ordinary bands or strips. With any form of mounting, the greatest strain is at the gripping points. Binding these with small rubber bands seems to even up and reduce the shearing strains at these points to a minimum. A simple hook, not small enough to cut the tubing, gives as good, if not better, results than more complicated forms of clamps.

In general, the motor must be designed first, and the framework as a whole made to receive or conform to the motor. The elements of design are, primarily, duration of power delivered, and the air-thrust required. As the necessary air-thrust, or reaction of the screws necessary to sustain the apparatus in the air, is directly proportional to the weight to be carried, other things being equal, the period during which the energy is being expended will vary in inverse ratio to the total weight.

While an occasional trial in the open air is desirable, to ascertain the effects of wind gusts and cross currents, the majority of small-model experiments can be tried indoors. With a speed of translation of 12 to 20 feet per second, a demonstration lasting more than 4 seconds will require a good-sized room or hall. As a flight of 4 to 6 seconds permits of observations covering the starting, launching, recovery of equilibrium, and alighting, to get best results the energy should entirely expend itself during this lapse of time. A single pure rubber tube, with 1/16 inch walls, measuring 9/16 inch in width when pressed flat, will develop a torque of 3 ounces at 5¼ inches radius; in other words with at the tips of a two-blade propeller 10½ inches in diameter. A thinner tube gives probably better results, and more easily adapts itself to its supports and frame. A single flat tube, ¾ inch across when pressed flat, 4 walls measuring 3/16 inch in thickness, is good for 1¼ ounces at 8 inches radius. Such tubes run about 2⅝ ozs. weight to a 6-foot length. Before winding up, small pin or needle holes should

be made throughout the tube, at intervals of an inch or two, to let out the air which will otherwise form bubbles likely to burst the tube. Two lengths of 16 inches wound together should fill the entire length with convolutions at about 72 turns, and at a 7½ radius develop a torque of about 2¼ ounces. With screws designed to run 12 turns per second, the energy, with this torque, would be expended in 6 seconds. A well-made screw of this diameter and speed will lift a weight, or exert a reactive force against the air, of from 3 to 5 ozs. Three tubes, 13/16 inch flat, 12 inches lengths, twisted together, developed a reactive torque at 7½ inches radius, as shown in the following table:

Turns	Torque in ozs.
0	0
5	½
10	1¾
15	2
20	2½
25	2¾
30	2¾
35	2¾
40	2⅞
45	3
50	3¼
55	3½

While the "still" torque will be seen to decrease rapidly, in practice the power discharged accelerates through more than half the distance, and the momentum of the screws acquired is sufficient to drive them at a speed which will maintain the machine in the air

after the rubber tube is seen to have entirely unwound itself. A chart or curve of the actual power delivered shows a considerable period where the discharge is fairly constant, particularly through that portion of the curve where the torque varies less than 20 per cent. A hélicoptère permits of a ready means of measuring the practical effect and power of screws in free flight, and with such apparatus a number of interesting determinations have been reached by the writer. As small models are subject to the same laws as the pendulum in regard to amplitude of vibrations, and a short pendulum vibrates much more rapidly than a long one, so a model of small dimensions must be enabled to recover its equilibrium with enormous agility where a larger structure might have some seconds in which to right itself. A hélicoptère with a pair of 15-inch diameter screws, and an expenditure of power similar to that of the table shown, easily lifts 10 ozs. total weight; such a model was one of those shown at the December, 1906, exhibit of the Aero Club at the Grand Central Palace. Its length over all was 26 inches, and it got into the air at about the end of a second's second. Mounted on small wheels, after a run of 12 feet it cleared the floor, and gradually ascended till the power was exhausted, alighting on the wheels some 70 feet from the starting-point.

There is a number of reasons why the hélicoptère type of air-ship is destined to compete with the aëroplane. For military purposes, particularly, the hélicoptère permits of hovering over one spot, or at least moving at a very slow rate of translation from one

point to another, if desired, for the purpose of making observations. The speed of an aëroplane cannot be reduced below a certain minimum necessary to maintain the apparatus in the air. The angles of ascent and descent may be made much steeper. A slower speed is made possible in starting and alighting, thus increasing the factor of safety for machine and operator. Owing to the smaller surfaces, the resistance to movement through the air is less, allowing a speed not possible for aëroplanes designed for low speeds. A one-passenger machine with operator need not weigh over five hundred pounds at the present state of the art.

While the power necessary for the hélicoptère may exceed that of the aëroplane by 20 to 40 per cent. in horse-power per pound of weight carried, this increased power becomes available for increased speed of translation when the machine is under way.

XIX

THE DIRECTION AND VELOCITY OF AIR CURRENTS

BY CHARLES FIESSE

THE general direction of the wind at various seasons, on all the seas navigated by man, and in most of the known countries, has been noted and catalogued. We know pretty well to-day the winds which may be expected at any season of the year on those seas and in those countries, in the lower strata of the atmosphere; but we have little knowledge of the conditions prevailing in the upper air, notwithstanding the amount of mountain-climbing done, and the balloon ascensions accomplished. I advocated, as far back as 1875, in an article published by the "Messager Franco Americain" (a French newspaper published in New York at that time), and later in a leaflet published in New York in 1892, entitled "The Study of Regular Atmospheric Currents," the use of balloons as means of ascertaining the direction, regularity, and velocity of the upper air currents. In this way we might be enabled to make use of them, as the Greek astronomer Hippale, for the first time in history, utilized the conjectural regular and periodic winds, called to-day the

mousson, to open communication and traffic across the ocean to a country unknown to the Greco-Romans of his time. It was only in the summer of 1905 that a systematic exploration of the upper air currents, in the trade-winds' region of the North Atlantic, was undertaken by Rotch and De Bort in a joint expedition; and the result of their observation of one of the most important of the regular winds flowing over the surface of the globe, has shown that such permanent winds are found in full force in the region of the Canary Islands, and that they blow until about 12 degrees from the equator. In winter their course is rather further south; but at all seasons a wind blows from, at least, 25 degrees north latitude, for fully 1000 miles southward, which, probably, before many years, will be taken advantage of in regular aërial voyages between America and Africa. The *ballons-sondes* adopted by Rotch and De Bort in their expedition, and also, more recently, by the expedition of the Prince of Monaco, furnish the means to rise to great heights, and to indicate by their drift the direction of the aërial current at different altitudes. Kites are also used, but in the trade-winds' region no great height has been attained by their agency. As a result of the work of Rotch and De Bort, we know to-day that the northwesterly current is drier and more rapid than the northeasterly current, and that there is always a quick rise of temperature as soon as the level of the anti-trade wind is reached. This change of temperature is one of the contingencies against which the aërial navigator will have to provide, in the same way as he should provide

for the lowering of temperature as he ascends in the atmosphere. It should be noted that if low temperatures are often experienced by the aëronaut, it was also ascertained by Rotch and De Bort that, with a temperature of 70 degrees just above the sea, the air at an altitude of 3500 feet had a temperature of 86 degrees Fahr. The Weather Bureau has recently adopted the use of *ballons-sondes* and of kites for the study of the upper air currents, and these will give better results to all interested in aërial navigation than the observation of cirrus and other forms of clouds by meteorological observers. But it would appear that for the purpose of aërial navigation, which is concerned mainly in the regularity, direction, and velocity of superior aërial currents (the direction of the inferior aërial currents being given every three months by the charts of "Patterson's Illustrated Nautical Encyclopedia"), an economical, rapid, and simple means of ascertaining the regularity, direction, and apparent force of the wind in the upper atmosphere is readily found in the use of the "smoke bomb" used by the Signal Corps of the U. S. Army. Such a bomb is loaded with a material which makes a smoke so dense that it can be seen at a great distance, and it is provided with a fuse that is lighted before the bomb is fired straight up from a small, light mortar. A gun of a certain description could be substituted for the mortar, as being better adapted to the use of the aërial navigator. When traveling, and even before starting on an aërial journey, we could by this means ascertain, in clear weather, the direction and velocity of an air current at a determined distance

from where the gun is fired, vertically, in order to take advantage of such current. If it be favorable, the trouble of ascending or descending is avoided, and voyages are made possible that shall practically benefit mankind. We foresee what promises to be a new means of intercommunication between different peoples, particularly those countries deprived of railroads and fluvial ways, such as the greater part of Asia, Africa, and South America.

XX

PROPELLER TESTING DEVICE[1]

By A. M. Herring

AMONG flying machine experimenters there is about as great a diversity of opinion in regard to the design of screw propellers as there is a dearth of actual knowledge of their efficiencies.

Perhaps not one experimenter in a thousand could answer any of these twelve questions correctly:

Given a screw of a certain diameter—

1. At what speed should it be revolved to give a certain thrust?

2. What combination of pitch and number of turns per minute would make it produce a given thrust with the least power?

3. Is it better to use a fine pitch and revolve the screw fast? or,

4. Is it better to use a coarse pitch and revolve the screw slower?

5. Is it better to use wide blades or thin ones?

6. Should the blades have a uniform or an increasing pitch?

7. Is it better to use two blades?

8. Three blades?

9. Four blades or more?

10. Given two screws exactly alike, but one two or three times the diameter of the other, how much more thrust should the larger give than the smaller when revolved at the same speed?

11. How much more power does it take to get a given number of pounds-thrust while traveling at 20, or 30, or 40 miles an hour, than it does to give the same thrust while standing still?

12. What percentage of the power used up is due to skin friction?

There are a dozen other points a flying-machine inventor should know definitely before he can attack the problem intelligently, since errors in the screw design may easily mean the need of an engine of from 30 to 100 per cent. more power than would otherwise be necessary.

To get reliable data on these points the apparatus herewith illustrated was designed, and on it some ten or more different sizes and types of screws have, up to the present, been tested out, both in still air and in a powerful blast of a known velocity.

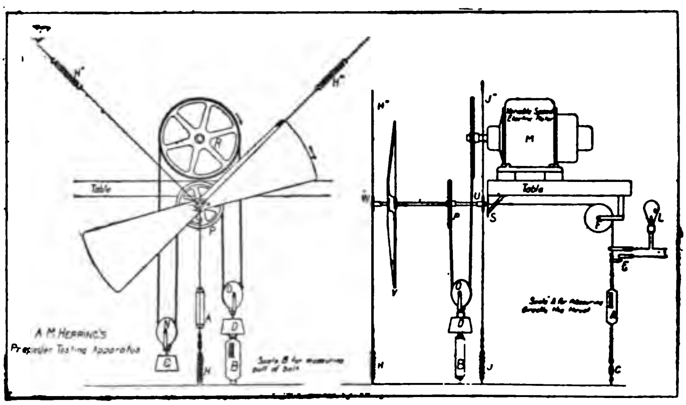
By referring to the drawings—

M represents a variable speed electric motor of about 5 horse-power. The motor is rigidly mounted on a table, and, by means of resistances and a controlling handle, may be kept running at any desired speed between about 700 and 1500 revolutions a minute at will.

The propeller *V* to be tested is mounted on a shaft *T* on which is mounted a pulley wheel *P*.

This shaft T runs in ball-bearings W and U and is held in place in the room by six wires H' H'', etc. These suspending wires have inserted in them turnbuckles for the purpose of adjustment, and very stiff springs for taking up vibration at high speed.

An endless belt connects the motor pulley R with the pulley P on the propeller shaft. This belt is made to pass under the ball-bearing pulleys H and O.



These pulleys have suspended upon them the equal weights C and D for the purpose of keeping the belt taut.

In testing, the speed at which a propeller is turning is measured at W where the shaft projects through the bearing.

The amount of power (foot-pounds per minute consumed in driving the screw) is the pull on the belt multiplied by its speed; or, to be more exact, it is the pull on the belt multiplied by the number of turns of the

pulley *P* per minute, multiplied by the circumference of this pulley in feet.

The circumference of *P* can be directly measured, and the pull on the belt is always exactly half the reading of the scale *B*.

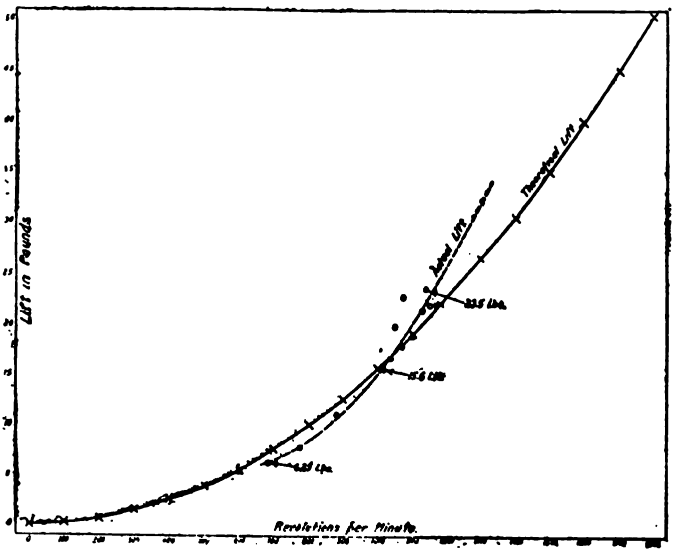
The thrust of the screw is measured directly by means of the scale *A*, which is connected by a wire with the bearing *U*.

A stop *S* prevents the shaft *T* from moving back beyond a certain point. An electric contact *E* and lamp *L* shows when the propeller pulls enough to move the bearing away from *S*.

The turnbuckle *G* is used for adjusting the force with which the propeller axle is held against the stop *S*, and which force must be overcome before the lamp *L* glows. This force—the actual thrust of the screw—is measured directly on the scale *A*.

Screws ranging from 7 inches to 4 feet in diameter were tested at some 15 to 20 ranges of speed each, and screws with wide and with narrow blades, but of the same diameter and pitch, were tried. Also screws of the same diameter and same number and width of blade were tried which differed only in pitch. A screw of 40 inches in diameter and having no pitch was also tested at many speeds to determine the power used in skin friction. As the apparatus was built throughout with great care, and ball-bearings were used everywhere, the friction of the apparatus itself is surprisingly small, so small that even in the experiment on skin friction the forces can be measured with accuracy. Incidentally the reduction of the thrusts of the various

screws caused by the wind pressure against the pulley *P* was arrived at with considerable accuracy by substituting pulleys of different diameter and noting the change in thrust of the screws when running at the same speed.



Herring's Propeller Testing Device.

To get an idea of the relative values of different designs of screws under conditions of actual practice a second motor (not shown in the drawings) was mounted in front of *IV*. A propeller was directly mounted on the shaft of this second motor and furnished a blast in which the screw being tested worked. And the second motor could also be driven at any desired speed, and the blast from it accurately measured.

The screws could be and were tested under conditions which closely approached those to be expected in practice where the flying-machine moves through the air in flight.

The results embracing some 900 or more readings has not yet been fully tabulated and analyzed, but enough has been done to see differences in design may easily mean great saving or waste of power.

The third figure herewith represents some of the results obtained with a moderately small screw—40 inches in diameter. The dotted line represents the actual pressures and speeds. The circular dots, outside of this line, are observations of pressures and speeds taken when a person stood near, and affected the flow of air to or from the propeller.

XXI

THE LAW OF ATMOSPHERIC RESISTANCE OF WIRES AND RODS

By Dr. A. F. Zahm
Catholic University of America

IT seems to be a fairly well established fact that the resistance encountered by blunt bodies of moderate size and similar figure, moving at low velocities in a fluid of constant density, varies as the square of their velocities, and as the square of their homologous dimensions. This was experimentally shown for spheres by Sir Isaac Newton, in 1710, by letting them fall from the top of St. Paul's Church, in London. ("Principia," Sec. VII.) His experiment was made to test a formula which he derived by integrating the impact of the individual steam-tubes of air against the front face of the sphere, neglecting its rear face, and assuming the impact of each stream to be the same as if it acted alone and uninfluenced by the other tubes.

Duchemin employed a similar method of computing the pressure. on the front of blunt bodies, without, however, neglecting the rear, but assuming there a partial vacuum, which he expressed as a function of the velocity ("Les Lois de la Resistance des Fluides").

He thus derived an expression of the form

$$R=av^2+bv^3$$

in which R is the resistance, v the velocity, a and b constants. This formula for blunt bodies seems to be corroborated for all speeds up to a thousand feet a second by the writer's experiments on projectiles. ("Philadelphia Magazine," May, 1901.)

RESISTANCE OF RODS AND STILL WIRES

The resistance of a round rod at moderate velocities is commonly assumed to be correctly given by the equation

$$R=kdlv^n$$

in which d is the diameter, l the length of the rod, and k and n are regarded as constants. But it has been an open question whether k and n are constants for very fine wires, and whether they have the same values for wires as for rods. The answer to this question formed one of the objects of some measurements made by the writer in April, 1903, and by one of his students, Mr. F. de S. Smith, in April, 1906.

We found that for rods and wires of all diameters, from 2 inches down to 0.009 of an inch, the exponent n is constant and equal to 2, very accurately. The coefficient k, however, remained approximately constant only for the rods, while for the wires it increased more and more rapidly with decrease in diameter, being about twice as great for the 0.009-inch wire as for the rods.

For still finer wires the coefficient of resistance may prove to be considerably more than twice as great as that found for rods. As the exact law of this variation of k was not determined, the publication of the results was deferred till more data could be obtained.

RESISTANCE OF VIBRATING WIRES

THOUGH no theoretical reason has been given why the coefficient k should be greater for stationary fine wires than for rods, it is apparent that a larger coefficient should be expected for singing wires. Let us investigate analytically the resistance of a single wire, supposing it to vibrate with the air stream, which is assumed uniform in velocity and direction.

Considering a point at the center of the wire, its resistance per unit length may be written

$$F=\mu(v-c)^2$$

in which v is the varying speed of the center of the wire, and c is the constant speed of the wind. As the center of the wire vibrates harmonically, its equation of motion may be written

$$x=a \cos \omega t$$

in which a is the amplitude, w the angular velocity of its reference point, x the displacement at any time t. Hence the instantaneous velocity of the middle of the wire is

$$v=\frac{dx}{dt}=-a\omega \sin \omega t$$

which, substituted in the first equation, gives

$$F=\mu(a\omega \sin \omega t+c)^2$$

as the force per unit length acting against the mid-point of the vibrating wire.

Evidently F is a variable force, being least when the wire moves fastest with the wind, and greatest when the wire moves fastest against the wind, and being $\mu\ c^2$ at its turning-points. To compute the average resistance throughout the vibration we may write

$$\bar{F}=\frac{1}{T}\int_{t=0}^{t=T} F dt=\frac{\mu\omega}{2\pi}\int_0^{\frac{2\pi}{\omega}}(a^2\omega^2 \sin^2\omega t+2ac\omega \sin \omega t+c^2)dt$$

$$=\frac{\mu\omega}{2\pi}\left[-\frac{a^2\omega \cos \omega t \sin \omega t}{2}+\frac{a^2\omega^2 t}{2}-2ac \cos \omega t+c^2 t\right]_0^{\frac{2\pi}{\omega}}$$

$$\bar{F}=\frac{\mu a^2\omega^2}{2}+\mu c^2 \text{ - - - - } (^1)$$

in which $T=\frac{2\pi}{\omega}$ is the period of one complete vibra-

[1] The relatively great resistance of fine threads is well illustrated by the remarkable shielding effect of thin veils. If a very open mesh veil form a single plane surface placed squarely across the wind, and the coefficient of each thread be 2, the resistance of the veil may be called twofold. If the veil form a closed surface, say a prism with fore and aft faces square across the wind, the resistance or shielding value may be called fourfold; for the wind meets a twofold resistance both at the front and rear surface, as it enters and leaves the prism. If the surface of the veil be oblique to the wind, as commonly worn, the shielding will be still more increased, owing to the obliquity of impact; for the transverse projection of the thread is the same in all directions, while the projected area of the mesh in the wind direction varies as the sine of the angle of impact. In close mesh veils the shielding effect is still further enhanced by the interference to normal flow through a mesh, due to the nearness of adjacent threads.

tion. This argument is the equivalent of saying that the average force multiplied by the period equals the integral of the instantaneous force multiplied by the element of time, both products being an expression for the impulse.

The final expression found for F contains two terms, the one, μc^2, being the resistance of a stationary wire in a wind of velocity c, the other being half the resistance of a wire in a wind having the velocity aw, or the fastest speed of the singing wire.

If, therefore, r be the ratio of the maximum wire speed to the wind speed, *i.e.*, $r = \frac{vm}{c}$, the resistance of the middle of the wire takes the form

$$F = \mu c^2 \left(1 + \frac{r^2}{2}\right)$$

and, if the maximum speed of the wire equals the speed of the wind, $r = l$, and, therefore,

$$F = 1.5 \mu c^2$$

that is, *the resistance of a singing wire at its center would in that case be fifty per cent. greater than the resistance of a stationary wire.*

Having found the coefficient of resistance for the middle of the vibrating wire, let us proceed to find the average coefficient for the whole wire. To this end let l be the semi-length of the wire, z the distance of any element, dz, from the center of the wire as origin, and x the amplitude of the vibration of dz. This amplitude varies from the value a at the middle of the wire

to zero at the fixed ends. For any intermediate point its value may be written

$$x = a\left(1-\frac{z^2}{l^2}\right)$$

as may be shown geometrically by passing a circle through the fixed ends of the wire and the turning-point of the vibrating center. Substituting this value of x, the amplitude of any element, in place of a in equation (1), we obtain the mean resistance per unit length for that part of the wire as

$$F=\frac{\mu}{2}\left[a^2\left(1-\frac{z^2}{l^2}\right)^2\omega^2+2c^2\right]$$

Having thus found the unit resistance of the wire at any point, we may integrate throughout its whole length $2\,l$ and obtain the entire resistance. Calling this R, we have

$$R=2\int_0^l F\,dz=\mu\int_0^l\left[a^2\left(1-\frac{z^2}{l^2}\right)^2\omega^2+2c^2\right]dz$$
$$=\mu l\left(\frac{8}{15}a^2\omega^2+2c^2\right)$$

Dividing the entire resistance of the wire by $2\,l$, the whole length, we obtain the average unit resistance; thus:

$$R=\frac{4\mu}{15}a^2\omega^2+\mu c^2$$
$$=\mu c^2\left(1+\frac{4}{15}r^2\right)$$

and if, as before, the fastest speed of the center of the wire equal the wind speed, $r=1$, and

$$R = \frac{19}{15}\mu c^2$$

We should, therefore, expect the resistance of a singing wire to be approximately one and a quarter times that of a still wire, if the speed of the mid-point of the wire at mid-swing equal the wind speed. The correctness of this deduction remains to be tested by experiment.

XXII

DISCUSSION OF ALEXANDER GRAHAM BELL'S PAPER

By Dr. A. F. Zahm
Catholic University of America

I FULLY concur with Dr. Bell in the opinion that aërial locomotion is practicable, and likely soon to be of great moment in the affairs of the world. For the progress of this science, during the past decade or two, has been as positive, as continuous, as substantial as that of any branch of engineering or of architecture. Constantly and quietly, in various parts of the world, men have grappled with the difficulties of this apparently hopeless problem; and now, I believe, we are about to enjoy the fruitful and splendid issue of their labors.

The subject of aërial locomotion may be divided into four main branches: first, the science of captive and free balloons; second, the science of motor balloons; third, the science of gliding and soaring machines; fourth, the science of dynamic flying-machines. Each of these has had its ardent advocates, and each is, I believe, practically feasible.

The first branch, or that of captive and free balloons,

is already a practical science, inasmuch as such balloons perform substantially the functions for which they are designed. The captive balloon can be sent aloft safely in all kinds of weather, for taking observations and making maps of the neighboring region, even in winds of upward of forty miles an hour. The free balloon, likewise, is comparatively safe if made by an experienced manufacturer and managed by a properly trained pilot. Such balloons may be kept aloft for days, or even weeks, traversing, in that time, hundreds of miles, or possibly the width of a continent, if the wind be favorable. But though we grant the practicability of balloons of this type, it must be said also that their functions are limited; their chief usefulness, thus far, being for the study of the atmosphere, for observations of the land beneath, for military operations, for public exhibitions, and, more recently, for racing and sport.

The ideal of the motor balloon is more important and more difficult, although this also seems about to be realized. The function of such craft is to go forth in all kinds of ordinary weather, to run in all directions, with or against the wind, scores of miles at a stretch, and to remain under perfect control. Salverda has shown, by reference to the yearly wind records at Paris, that aërial navigation may be practically realized for that locality when a vessel can be driven 28 miles an hour. Is such an achievement possible? More than a decade ago theorists demonstrated mathematically that this speed, and even higher, was attainable by appliances then known. Now apparently the inventors, taking a

lesson from Santos-Dumont, have caught up with the computers, and are producing the high-speed balloons. On the third of this month, an eye-witness told me that he saw Count von Zeppelin's air-ship fly about Lake Constance at a speed of 28 miles an hour, independently of the wind, and that she obeyed her rudder as perfectly as does a boat on the water. It is reported that the inventor has deduced from these experiments that a larger vessel will operate still more effectively, and that an air-ship of this type can be made to carry fifty passengers at a speed of more than thirty miles an hour. Count von Zeppelin writes that his present balloon, which is 410 feet long and 38 feet in diameter, has attained a speed of 33.5 miles an hour, and is able to go 1860 miles through the air at a speed of 31 miles, or 3000 miles at a speed of 25 miles an hour, without stopping for supplies. Let me add that, to match this achievement in Germany, the French government has just accepted the fine new Lebaudy motor-balloon and has ordered two more like it, thus adding three modern air-ships to her aërial equipment. Such facts may give us at least a little faith in aërial locomotion of the second kind.

The aim of the gliding and soaring machines is to travel through the air on motionless wings, without the aid of gas or motive power, by the sole forces of wind and gravitation; not only to glide downward, but also to soar up to the clouds, and sweep over vast territories, as do the condor and the albatross. To some people this seems absurd; but there are the vultures and the gulls performing the impossible every day. Humboldt

assures us that the condor can soar from the Pacific to the heights of Cotopaxi and Aconcagua without a wing-beat. Here is a splendid field of research which thus far has remained practically unexplored.

Unfortunately, I can not quote an instance of real soaring by man; that is to say, gliding to an indefinite height and distance without the use of motive power. Still, from the mechanical nature of the performance, I believe it to be feasible. Dr. Langley was so convinced of the possibility of this kind of flight that he looked forward to the time when man would soar over vast distances, and possibly circumnavigate the globe, without the expenditure of motive power, save in those regions of the atmosphere where there might be an extended calm or downward trend of the wind.

Two years ago the Wright Brothers compared their power of aërial gliding with that of a vulture in North Carolina, among the Kill-Devil sand-hills. On a day when there was little or no wind, they observed a buzzard tobogganing down the atmosphere, parallel with the sloping sand, and very near to it. Where the slope was steep enough the bird could glide indefinitely without wing-beat, but where the incline was too gentle, say seven degrees or less, the buzzard had to flap its wings a little to maintain its flight. Having carefully noted a considerable stretch of sand where the bird could barely sail without flapping, they mounted their glider and skimmed over the same slope without motive power. From such experiments they concluded that they could glide fully as well as the buzzard, and possibly a trifle better. In other words, if they were placed

on a perch in a large closed room, in competition with the bird, they would probably win the prize for long-distance gliding.

In one other feat, also, they imitated the vulture. They hovered motionless above a sand slope for 59 seconds, neither rising nor falling, neither advancing nor receding. In this case, of course, the wind had a slightly upward trend, say of seven or more degrees, just as must be the case when any bird floats fixed and motionless in the air.

I put this question to them recently: "After beating the buzzard in the art of gliding, did you try to beat him in the art of soaring up toward the clouds?" They replied that nothing would have given them more pleasure; but their power machine, on which they had worked so arduously and so long, was ready for its first test, and Christmas was just at hand. So they went out in a bitter gale, launched their motor flying-machine in the teeth of a tumultuous thirty-mile wind, and flew half a mile through the air, or three hundred and some feet over the ground. Thus ended their gliding and thus began their dynamic flight.

But they still envy that feathered professor of the atmosphere, and still have confidence that they, to some extent, may acquire his fascinating art. If they could dispose of their present power machine, doubtless they would return again to the sand-hills and plunge pell-mell into the soaring business.

As to the fourth type, the motor flying-machine, I need add little to the excellent summary given by Dr. Bell. Without radical improvement, such machines

may be driven through the air with the speed of the eagle, and made to carry several hundred pounds' burden. The Wright Brothers, in their recent communication to the Aèro Club of America, conclude with these words: "It is evident that the limits of speed have not as yet been closely approached in the flyers already built, and that in the matter of distance the possibilities are even more encouraging. Even in the existing state of the art, it is easy to design a practical and durable flyer that will carry an operator and supplies of fuel for a flight of over 500 miles at a speed of 50 miles an hour."

In a great conflict like the recent Oriental war, one such machine could do more reconnoitering than 50,000 armed men. For, in a few hours, it could completely survey and snap-shot the enemy's field of operations, though covering hundreds of square miles. A fleet of such machines, armed with bombs and fire pellets, could devastate the whole of an enemy's border, both towns and villages, unless opposed by other flyers. Possibly, also, a fleet of this kind could protect a nation's seaboard against the attack of battle-ships, unless the latter were accompanied by an aërial squadron. Therefore, if one great nation keeps flyers, all the world powers must have them.

But this seems like hunting for trouble with a searchlight just before daybreak. Whatever be the mission of the flying machine, I think we may say of it as the English do: "The thing is bound to come, whether we like it or not." "And damned be he who first cries hold!"

As to Dr. Bell's researches in this interesting and now popular field of inquiry, I would say, first, that every earnest friend of science should be very grateful to him for lending his illustrious name to a much ridiculed pursuit, at a time when it jeopardized one's place and good name publicly to promote mechanical flight. I well remember with what apprehension Mr. Chanute consented to become chairman of the first international conference on aërial navigation in this country. And we all too well remember the attitude of many people toward Dr. Langley's painstaking and unobtrusive investigations. The Wright Brothers, also, experienced hostile treatment in certain quarters before their success was known. Even after the news of their splendid flights of last year had been circulated privately among their friends, we heard many apparently intelligent dogmatists assert that it is not the design of Providence, or of nature, that a human being should fly; and that, furthermore, the performance is manifestly impossible. This is another illustration of the value of public opinion in matters of technical import. But, fortunately, the destinies of science are not dominated wholly by the vote of the majority, nor yet by grand officials, whether legislative or executive; else, I fear, we never should have either a science or art of aërial locomotion.

Another service for which we may thank Dr. Bell is his having met publicly, both by model and by argument, a profound objection of the mathematicians, based on that ancient Euclidean theorem connecting the surfaces and volumes of similar figures with cer-

tain powers of their homologous linear dimensions. Dr. Bell did not deny the law, as a chagrined or an angry person might have done; but, like a shrewd man of affairs, he admitted the law, and discovered a way to evade it.

Now that his reply is familiar to us, it may seem amusing that people urged the Euclidean objection so strongly; but the fact is that many persons, besides Professor Newcomb, advanced it as an argument against the practicability of mechanical flight. In the middle eighties an eminent geologist made it the basis of a magazine article, in which he proved, with lovely eloquence, that it is impossible for a human being ever to fly. He further supported his contention by a vigorous biological argument, and possibly also by a theological or teleological one,—I do not remember. He asserted that for centuries nature had tried to produce a flying creature as heavy as a man, but had failed; therefore, it is utterly impossible for man to achieve mechanical flight. By diligent experimentation she had tested and adopted the strongest possible materials, she had developed the most powerful motor for a given weight, she had employed the most favorable shapes and the most efficient mode of propulsion. But what was the outcome? Her largest flyer weighs hardly as much as a human dwarf. The ostrich is the limit. The ostrich is the living witness of nature's failure. And that picturesque old reptile, with the twenty-foot wings, that once soared so grandly over the Cretacean seas, remains to-day the fossil proof of nature's utmost capacity, and, therefore, also of man's.

Such arguments, such prettily woven sophistries, such quaint immemorial cobwebs, have Dr. Bell and his associates brushed reverently from the pages of science.

There are many features of Dr. Bell's remarkable kites, both structural and aërodynamic, that merit most careful attention; more particularly the relation of the forward resistance to the total uplift, the effectiveness of the provision for automatic stability and equilibrium in all kinds of tumultuous winds, the distribution of stresses in the frame, and of the impulsive pressures over the sustaining surfaces. But these topics seem to me more suitable for experimentation than for abstract analysis.

One interesting phenomenon, however, I will notice in closing. Dr. Bell relates that his floating kites which, in calm weather, could advance but four miles an hour, still continued to make headway against a sixteen-mile wind. The momentum of the craft might maintain this forward motion for a few seconds, but not for a considerable period. For the total momentum in any direction is equal to the initial momentum plus the impulse of the resultant force in the line of progression. Or, in the language of algebra,

$$mv = m_0 v_0 + (F - F')\, t,$$

in which mv is the momentum at the time t, $m_0 v_0$ the initial momentum, $F-F'$ the resultant of the average propulsive and opposing forces. If mv is positive for large values of t, the equation shows that F must at least equal F'; but Dr. Bell observed that the kites continued always to advance, or that mv remained positive. Therefore, the propulsive force continued,

on the average, at least equal to the resistance. In other words, it was the propeller thrust, rather than the momentum, that maintained the indefinite forward progression.

But how, it may be asked, could the propeller thrust maintain headway against a sixteen-mile wind, if, in calm weather, it could support a speed of only four miles an hour? I would answer: first, that the water resistance was not greater in the sixteen-mile wind, but probably less; and second, that the propeller thrust might be not very different in a calm and in a sixteen-mile wind, as Maxim found. This latter point Mr. Manly can elucidate readily from his extensive study of both the theory and actual working of screw-propellers.

It is well for the world when a man of Dr. Bell's fertility espouses some favorite science. He took up the kite as a toy, and now presents these wonderful structures; light and beautiful as butterflies, yet strong and stable enough for human life. If next he incline to magnificence, what lovely air-castles will follow! Serenely, one day, may he soar in a gossamer palace, when the blue waves blossom, and the wind sings over the sea!

XXIII

HOW I BECAME A PILOT

By J. C. McCoy

ONE may be expected to prepare for his first balloon voyage with feelings of vague alarm at the thought of the almost certain dangers to be encountered in the regions of the upper air, so as I drove through the Bois de Bologne one morning last August, on my way to the Aero Club Park at St. Cloud, my mind was troubled and filled with doubt, for I was about to take the first step toward becoming a *pilote aëronaute* of the Aero Club de France.

It happened this way: Mr. F. S. Lahm, dean of the pilots of the Aero Club of France, and dear to the hearts of every aëronaut who visits Paris, was much interested in forwarding the success of the new Aero Club of America, of which he is a distinguished member.

He knew the young club was strong in numbers, for the year-book, just published, showed a long list of members whose distinguished names commenced with all the letters of the alphabet from A to Z. He knew they were rich in money, for they had an address on one of the most expensive corners of upper Fifth Ave-

nue, where they looked out upon the hurrying throng of wealth and fashion.

He knew they had balloons, for Count de La Vaulx had braved the perils of the deep to bring them the *Centaur,* that scarred veteran of innumerable ascensions, old in years and feeble, but famous as a winner of world records, and *L'Orient,* not so old perhaps as its companion, but without its memory of achievement to give value to its declining years.

To us this seemed all that was necessary to make the Aero Club of America a grand success; but Mr. Lahm, who had lived abroad many years and had all the advantages of foreign training, knew that we needed something more; he knew that the club needed a pilot, and as I was the only member of the club in Paris at that time he selected me for his victim and proceeded to make me a pilot.

He accomplished his design in this way:—first, he talked to me for hours at a time of the delights of ballooning, in a way that was irresistible, until my enthusiasm was aroused, and then talked to me for more hours about how safe it was, until my fears were all dispelled, or perhaps, I might say, until I was ashamed to admit that I had any fears, and then turned me over for further treatment to his son, Lieutenant F. P. Lahm, who has since become famous by winning for the Aero Club of America the Gordon Bennett Cup.

It soon developed that the way to become a pilot was long, and dark, and dangerous; for the Aero Club of France, the arbiter of all things aëronautic, had just decided that in order to qualify as a pilot one must

make ten ascensions, one of which must be made at night, and two of which must be made alone. In the days of Pilatre Rozier, the old way of becoming a pilot was to get your own balloon and go up in it, and that made you a pilot. Of course, if anything happened on your trip, as it did with him, and you had to walk back, you were a dead pilot, but a pilot just the same, for in those days there was no Aero Club of France to make regulations.

Although I was inclined to demur at making balloon trip in the dark and two trips alone (I did n't like that), these new regulations of the Aero Club of France appeared better than the old way, and that is why I drove through the Bois de Bologne that August morning on my way to St. Cloud.

The morning had promised fair, but while on our way the clouds gathered, and as we crossed the Pont de Suresnes the river below was dimpled by the falling raindrops, and we could see the smoke from the tall chimneys of Puteaux driven by the wind toward the northeast, but holding close to the ground as though reluctant to venture higher. At St. Cloud we found the *Katherine Hamilton* filled to the neck, safely housed in the huge aërodrome to protect her from the hurrying gusts of wind which rushed down the Seine. Ready to start, she stood gently swaying back and forth, moved by the eddies of wind which found their way in through the unprotected end of the *hangar,* and seemed impatient to bound upward on her flight.

Intervals of storm followed sunshine, and delayed our departure some hours; but finally there came an in-

terval in the storm, an expanse of blue sky overhead, brilliant with sunshine, and, making hasty adieux to attending friends, the pilot cried "All hands let go!"

We did not move, but earth and friends quickly receded from us, without motion, and so gently that only increasing distance and gradually fading view told us that they were going. Hanging there, high in midair, they left us, while they quietly dropped away further and further, until our friends seemed mere specks beneath us. There we hung, high above the fast receding earth, until our gradually extending view sped far beyond Paris, now beneath our feet, across streams and past villages, to where fields and forests met the rising horizon.

Not once had we moved. Our basket, steady as a rock, seemed to stand on the point where left by departing earth, and passing before us was a rapidly moving panorama of busy life. Far below stretched the network of Paris streets filled with little black points, always crawling with down-turned eyes, and unconscious of our presence above them. The street sounds came to our ears with great distinctness, but as from far off, and as the earth moved on beneath us they faded away.

Now we were over the country, which lay spread before us like a great map on which the roads, like broad white lines, stretched away in sweeping curves until lost in the haze of the distant horizon. Little villages, nestling in protecting bends of the river, or sunning themselves on the level plain, swept by us, greeting us noisily with shouts of excited welcome and invitations to descend. Peasants in the fields stopped their labor, and,

with upturned faces, waved greetings until lost to view. It was as if all below were covered with an Oriental carpet of intricate design, the brilliant coloring of growing and ripened crops in striking contrast to the somber hues of freshly-turned earth.

A covey of quail, feeding in the stubble of newly-reaped grain, scurry for shelter with shrill notes of alarm; and a rabbit, with awkward lope, hurries to escape. Nature's secrets seem to open before our eyes as we look through the waters of a great river and read its depths. Stately châteaux, on the edge of vast forests, hidden from the world of travel on great highways, meet our view; and as these proud relics of bygone days lay bare to us their beauties and their grandeur we seem to have trespassed on countless years. Away toward the sunlight a winding stream glistens like molten silver, and far, far away, where all else is lost to sight, we detect its presence by splashes of glittering light.

We are above the clouds, which shut out all view of the earth below. The brilliant sunlight on the masses of white clouds, which pile up in the most fantastic forms, make a most unusual sight. Impression has crowded on impression with such rapidity, bringing sensations so thrilling that I have been oblivious to what has been happening in the balloon.

The instruments show that we have started down. As we reach the heavy bank of clouds the balloon rebounds upward, as though unable to find an opening through which to pass. Again and again we approach the clouds, only to be skipped along their surface, as a

stone is skipped along the top of a stream, until finally we drop through an opening, and once more see the earth.

Darkness is fast approaching, and the moisture and cold of the clouds through which we have passed have caused the gas to condense, so that the great bag above us, which in the sun above the clouds a moment before had looked as tight as a drum, is now flabby. Our instruments show that we are falling fast, and I am struck with wonder to see the sand which Lieutenant Lahm is hastily throwing overboard defy the law of gravitation and disappear above us as it shoots upward. When our rapid fall is checked by the loss of ballast, and the sand comes down upon our heads, I learn that we had been falling so fast that the sand could not keep up with us.

It is a thrilling experience to think of, but one without danger, as I will prove to you the first time you make an ascension with me, if you are inclined to try it.

With checked velocity we approach the earth, and the practised eye of the pilot scans the ground ahead for a suitable landing-place. As we come lower I know that he cuts loose the great iron anchor that has hung heavy on the basket side, and I hear it strike the earth with a dull thud. The anchor rope draws taut and brings us to earth. The great balloon lies at our feet—a writhing, twisting thing out of which the life is slowly ebbing. We are at Coucy les Epps, 150 kilometers from Paris.

From all sides come running peasants, excited and beaming with delight over such an unusual event. Wil-

ling hands make short work of packing up the balloon, which is soon loaded on one of their great two-wheeled cars, and we are on our way to the railroad station, some twelve kilometers away. Just in time, for the storm which has followed in our rear since we left St. Cloud overtakes us and we are caught in a downpour of rain. A kind-hearted peasant woman hurries after us and insists on our taking her umbrella, and we are saved a soaking. The rain does not disturb our driver and his young son, who keep up a most cheerful song all the long dark way to the station, and accept our fee with many expressions of gratitude. As we wait in the dimly-lighted station for the train, we eat the little luncheon and drink the bottle of white wine which had been put up for us in the morning at the little café on the banks of the Seine at St. Cloud, all the while objects of great interest to the crowd of peasants, who have identified us by our luggage as belonging to the balloon which had passed over them a short time before.

My first trip did not advance me far in the direction of becoming a pilot, for I had been too much absorbed by the wonders of the voyage to give attention to the pilot; but in the trips made later I learned some of his skill and experience, so that when I came to make those two trips by myself they were no longer cause for alarm, and I departed alone in the basket without misgivings. The trip at night proved to be a thing not of darkness, but an experience full of wonderful impressions which will never be forgotten.

Finally the many trips required by the regulations of the Aero Club were finished; and at a meeting of the

Commission Sportive, after carefully considering the record of the trips which had been made to the club, they solemnly declared that hereafter I should be known as a *pilote aëronaute*.

APPENDIX

RULES AND REGULATIONS GOVERNING THE ISSUE OF LICENSES TO AËRONAUTIC PILOTS

ARTICLE I

Applications may be made in writing to the Board of Directors for a license as aëronaut pilot by any member over 21 years of age who has made ten (10) ascensions. Of this number one must have been made at night, one alone, two of the ten must have been conducted by the applicant himself under the supervision of experienced aëronauts who have been approved by the Board of Directors, and who shall report to the Board on the manner of the applicant's handling of the balloon.

On the two last-mentioned trips the observers shall not in any way interfere or give any advice as to the management of the balloon from the time balloon leaves the ground till the time of final descent.

ARTICLE II

The Board of Directors may, without assuming any responsibility for themselves or for the Aëro Club of

America, issue a license as aëronautic pilot on such application when, in their opinion, the applicant is fully qualified, and when they are satisfied that his methods of flight are reasonably prudent and safe, and that he is a person of such sound judgment and discretion as to entitle him to assume such responsibility; or they may, in their discretion, refuse to grant such license.

ARTICLE III

The Board of Directors may, upon written application, grant a license as aëronautic pilot to any member holding such license in any affiliated foreign club.

ARTICLE IV

Any member whose application for a license under Article I has been refused, may not again make application until after a lapse of six months, and until after he has made five additional ascensions.

ARTICLE V

The Board of Directors may, in their discretion, suspend or revoke any license issued under these rules.

RULES GOVERNING COMPETITION FOR THE LAHM AËRONAUTIC CUP

THE Lahm Aëronautic Cup is offered by the Aero Club of America for contests of distance in the United States, and is open to members of the Aero Club of America or any affiliated club in the world.

This contest is instituted by the club to commemorate the victory of its representative, Lieutenant Frank P. Lahm, in the first contest for the Gordon Bennett International Aëronautic Cup, starting from Paris, France, September 30, 1906, crossing the English Channel and landing at Fyling Dales, England, October 1, 1906, after traveling in the air a distance of 648 kilometers, and defeating fifteen competitors representing the highest aëronautic skill in Europe.

REGULATIONS

ARTICLE I

The contest is open to all aërostats, aëronats and aëronefs, without restrictions, and a contestant is at liberty to start from any point in the United States of America at any time that he may desire. Contestants must be either licensed pilots or they must have already made ten ascents. In the latter case, the con-